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A STRUCTURAL STUDY OF THE CATERPILLARS: III, THE SOMATIC MUSCLES.

Wm. T. M. Forbes, Ph. D., Worcester, Mass.

In consideration of the very few dissections of the muscular system of Lepidoptera which have been published, and their radically different interpretation, it has seemed advisable to study a few more forms and trace if possible the points of disagreement.

PREPARATION.

A serious matter in such a research is the preparation of material. The muscles are small and slender, quite difficult to trace without a good microscope and plenty of light, easily broken in dissection in hardened material, and almost perfectly transparent when fresh. Besides this they do not differ in color from the fat with which they are intermingled, and when preserved in formalin hardly differ in consistency. The most satisfactory material was opened out after killing with cyanide, and pinned out on a piece of cork; then treated with strong corrosive sublimate (bichloride of mercury) and dissected while immersed in a dilute solution of the sublimate. This makes the muscles intensely white, distinguishable from the fat by their silky luster; but the mercury attacks dissecting instruments badly and so most of the work was done with material preserved in formalin (4 per cent., that is, 10 per cent. of the commercial solution). Alcohol was also tried, and was nearly as good; the muscles being darkened

a good deal in some cases, which made them more difficult to see in a dim light, but brought them out in contrast with the fat. For the work with the thorax it is important to open up the caterpillar and pin it out before hardening, as otherwise many of the muscles will be broken. If specimens are to be preserved whole for dissection purposes they should be killed in hot water, or injected with a stronger solution of preservative to prevent decay. The prothorax and last segment are particularly hard to get in a satisfactory condition, because of their peculiar shape, and the close connection of the former to the head, which should be split vertically when opening the caterpillar. It is most convenient to open the caterpillar near, but not quite on the middorsal line.

The viscera and loose fat of the body cavity are removed as a preliminary, as well as the wings of the heart, leaving the heart, trunk trachea and nervous system as long as possible for landmarks. The dissection can follow the order given by Lyonet, to advantage, but it is often unnecessary to open any specimens by the venter, as the dorsal musculature is comparatively simple, and is often uninjured on one side. Plate XIX follows this order fairly closely in its six stages, but in other plates less stages are shown for economy.

It soon appeared that the muscles represented by Lyonet, for the Goat moth caterpillar, could be found in such widely divergent forms as a Sphinx, a Noctuid and a Lasiocampid, so his lettering is used in the figures. Lubbock's dissection was hardly as perfect, while Berlese's figures are wholly diagrammatic and useless for the study of homologies; in fact several of his comparisons with the muscles of other insects are invalid. We will only be able to come to a true knowledge of the homologies when the nerve-muscle relations are fully worked out; and in the Lepidoptera the matter is much confused by the anastomoses between all three pairs of nerves, and even between successive segments.

THORAX.

To go on to details; I have not made any satisfactory dissection of the *prothorax*. Evidently however, Lyonet represents the state of affairs much more accurately than Berlese. The dissection figured on Plates 1 and 2 may be taken as accurate so

far as it goes, but is incomplete. The following comparisons may be made between Lyonet's, Lubbock's and Berlese's lettering:

LYONET.	LUBBOCK.	BERLESE.
C^+	82	CXXXIXa
D, E	1, 4, 5	139–140
A	6, 7	140b
α	22	CXXXIX
G, H, I, L	61, 62	CXXXIV
β, γ, δ, etc.	35, 76, 80, 81	CXLI
a, b	16, 17, 21	CXXXII
ζ	19, 20, 26	CXXXIIa
c	18.	CXXXIIb
r, etc.	77	129
i, l, etc.	70, 71, etc.	147
u, v	57, 58	XL

The whole arrangement is complex and only in a general way comparable to that of the other segments. C^+ is interesting as extending well beyond the segment line, and in Cossus the length of two whole segments—being the longest muscle in the caterpillar. It also crosses the middle line in Cossus, but not in Noctua, where it is shorter. If Lyonet is correct there are no longitudinal muscles within the nerves, (except perhaps the aberrant A and C^+ which presumably represent the great longitudinal muscles of the following segments); and some of the muscles are innervated from the subœsophageal ganglion, evidently belonging to the cervical system. The spiracle is supplied by the "bride epiniere" or so called sympathetic fibre, derived from the same segment, but it runs largely in the following one and seem to supply also some of its muscles, besides anastomosing with its first nerve. This indicates strongly that the spiracle originally lay on the incisure, as the rudimentary second one actually does, and that it has moved forward. For the same reason we see that the other spiracles have moved back, being supplied by the nerve of the preceding segment; and all the spiracles are accounted for.

The *meso-* and *metathorax* are perfect counterparts of each other, and strongly contrasted with the other segments in structure. The few points of difference between them noted by Lyonet, are further reduced by the correction of a couple of misinterpretations, and particularly by treating the three bellies of his α as separate muscles. In discussing these, and the remaining segments we may use Berlese's division of the

segments into four annulets, illustrated on Plate IX, Figs. 1 and 2. These are the acro-, pro-, meso- and meta-tergites and sternites, separated by the antecosta, precosta and inter-costa. The tergopleural suture is indicated only by the position of the rudimentary wing, while the pleurosternal one is the strongly marked subventral fold, to which several muscles are attached. In the abdomen these boundaries are less distinct, but the pleurosternal suture can be traced in a general way, and the tergopleural must be placed at least a little higher, as indicated by the spiracle, which should lie within the pleuron. Of the true legs we have a well marked coxa, which is mostly membranous in the Sphinx, a strong femur, to which only one or two small somatic muscles are attached, and the rudiment of a trochanter, which bears the insertion of r. The insertion of the various muscles of the leg is beautifully shown by Lyonet, in Plate VIII, Fig. 7. In Cossus where the coxa is wholly chitinized k, n, p, s, t, u, v, x, ϵ, ϑ, κ, λ, μ, ν and ξ run to it. The body muscles may be divided as to their origin in the embryo into the dorsal and ventral longitudinal systems, and the lateral and ventral transverse ones; the last is not represented in the caterpillar by a developed muscle, but its rudiment may exist associated with the fork of the sympathetic nerve and the ventral diaphragm. This would be 4 of Berlese. The lateral transverse muscles are again divided into two sets, between which lies couple of longitudinal fibres (E of the abdomen) and the trunk trachea, but as the trunk trachea is not well developed in the thorax, and replaced by collaterals in the body cavity, the muscles must there be treated as a single unit. If we consider C, E and G as homologues of E, etc., of the abdomen θ will be the only fibre of the deep set in the thorax, as it is in the abdomen. It should be noted that the spiracles can migrate without disturbing these fibres, while the deep transverse fibres would have to be swept before them. The muscles also differ from each other in their normal or oblique direction, their length and their insertion. The table annexed classifies them, and gives the relations between meso- and metathorax, and between the various nomenclatures, omitting those muscles which puzzle me.

	LYONET		LUBBOCK	BERLESE	
	Meso-.	Meta-.		Meso-.	Meta-.
LONGITUDINAL DORSAL.					
Rectus (1)	A	A	1	70	37
	B	B	1	70	37
Oblique segmental	C	C	8	70b	37b
	E	E	8′		37c
	D	D	5	70a	37a
	F	F	5	70a	37a
	G, H	H	4		
	α (1st belly)	G	6, 7		
Shorter segmental	I	I			
To intercosta	K	K	61		
From precosta	L, M,	L,	9-11		
To precosta	S	S	62		
	T	T	63		
From intercosta	Q	Q	12, 13		
	R	R	14, 15		
To antecosta	λ (part)	λ (part)	64, 65 (part)		
INTRANEURAL (2)	c	c	18	+	
LONGITUDINAL VENTRAL, SUPRANEURAL					
Segmental	a	a	21	LXXII	XXX
	b	b	17	"	"
	–	d	(16)	"	"
	e, f	e	22	+	
	d	f	20	LXXII	XXX
	g	g	16 (19)	"	"
	h	h	23	"	"
To mid-ventral line behind coxæ	l	l	26	+	
LONGITUDINAL VENTRAL, SUBNEURAL					
To mid-line in front of coxæ	i	i		IVb (3)	
Crossed to front of coxa	k	k	24	IVa (3)	
Short anterior transverse (4)	z	z	25	+ (3)	
From mesosternite at mid-ventral line	n	n	28	+	
From precosta	m	α (3rd belly)	77		
Short fibres from leg	q	q	79		
	u	u	57	V=Iα	
	v	v	58		
TRANSVERSE; TO PLEUROSTERNAL LINE					
Antecosta to prosternite	β	β	49		
Precosta to precosta, superficial	δ	δ	49		
Precosta to prosternite, deep	ν	ν			
Precosta to mesosternite	μ	μ	72	XVIIIa (3)	
Antecosta to posterior incisure	ϵ	γ	66	XXXIVa	
Antecosta to mesosternite	λ	λ	70	XVII (3)	
	(posterior bellies)		65 (part)		
Intercosta to mesosternite	κ, ξ	κ, ξ	50	XVIIIa (3)	
Anterior incisure to precosta	γ	α (2d belly)	76		
To anterior incisure	η	η	40		XXXVIb
	w	w	41, 42		

	LYONET		LUBBOCK	BERLESE	
	Meso-.	Meta-.		Meso-.	Meta-.
ACROSS PLEUROSTERNAL LINE					
Intercostal region to leg	ζ, ϑ	$\epsilon, \zeta, \vartheta$	46, 51	5*a* (3)	5
Posterior incisure to leg	t	t	55	XVIIβ (3)	
Superficial on incisure	θ	θ	35	XXXVI	XVIIa
Deep on incisure	x	x	34, 38	XXXVIa	XVIIIa
BELOW PLEUROSTERNAL LINE					
To leg	s	s	78	IIa, 6a	
To near midventral line	p	p	73-75		
SPIRACULAR (rudiment)		π			

NOTES: (1) *Muscles droits* of Lyonet.
(2) Passing between the two longitudinal connectives.
(3) Fig. 478.
(4) Certainly derived from longitudinal muscles like k. In the mesothorax it tends to cross the middle line.
\+ Indicates that the muscle is represented but not named.

The wing is shown in the deepest layer of the dissection on Plate XVIII, in its normal position. The only fibres closely associated with it seem to belong to w and λ, practically all the pleural muscles being inserted far above it. Evidently the pleurites are very slightly developed in the caterpillar stage.

The *mesothorax* seems to differ from the metathorax as figured only in having a fibre or two more or less in the case of such homologous muscles as a, b, (d); β; Q. R. S and T. The union between thorax and abdomen is made with only a single disturbance of the musculature, aside from the fact that the ante- and precosta of the first segment of the abdomen are undeveloped; and that is that one head each of E and F have moved forward a short distance beyond the incisure, carrying with them a couple of fibres of θ, and attaching themselves to the insertions of G and t respectively.

MIDDLE SEGMENTS OF ABDOMEN.

One of the middle segments may be taken as typical of the abdomen. Examples of three families are figured on Plates XX, XXI and XXII. As compared with the thorax the most striking difference is the weak development of the oblique lateral muscles, and the absence of muscles that cross the median line; both conditions correlated with the simpler movements of this part of the body. Here also there are no such confusing cases as α of the thorax, where several morphologically widely separated muscles form a single functional unit. There is no

fibre piercing the nervous system, and no short dorsal anterior muscles, though it was probably such a muscle ventrally, that gave rise to p′, which is wholly independent of p and x, though not well marked in Cossus and Malacosoma. In the abdomen the principal nerve divides the ventral muscles quite centrally, forming the most satisfactory distinguishing character between the fibres f and g, and forming the most fundamental distinction between a and the other recti; the relation of the dorsal muscles is more obscure, as the nerve divides up, but A, B and C evidently lie above, and E, F and H below it. The transverse muscles are divided into two groups as already noted in the case of the thorax. The following classification of the muscles gives their designation by Lyonet, Lubbock and Berlese.

	LYONET	LUBBOCK	BERLESE
LONGITUDINAL DORSAL			
Rectus	A	1	VII
	B	3	"
	C	2	"
Segmental	D	4	"
	G	5	"
From antecosta, oblique	F(4)	8	X
	H	7	"
From antecosta to antecosta	E	6	IX
From precosta	I	9	XI
	L	10, 11	"
From intercosta	Q, R	12, 15	XVI
LONGITUDINAL VENTRAL, SUPRANEURAL.			
Rectus	c	18	2
	b	17	"
	d(3)	16	"
Antecostal, oblique	f′ (in Malacosoma only)		
Longitudinal segmental	e	20	2
	ff	19	"
To antecosta of following segment	f	25	IV
From antecosta, oblique	h	+	
LONGITUDINAL VENTRAL, SUBNEURAL.			
Antecosta to antecosta, longitudinal	a	21	III
	i	22	"
To antecosta of following segment, oblique	g	24	IV
Segmental, oblique	g′	25	2
From front of leg	k	27	1 aα
From near midventral line, between legs	p	28-30	1a
From posterior side of leg	t	57	V
From leg toward mid-ventral line	x	56, 58	1aβ (1)
From near mid-ventral line to leg	(p′)	46(part)	1aβ
SPIRACULAR	M	45	
TRANSVERSE SUPRATRACHEAL.			
Acrosternal	θ	35	XVII
At precosta	θ(2)	36	"

	LYONET	LUBBOCK	BERLESE
TRANSVERSE SUBTRACHEAL, *Above subventral fold.*			
From near incisure to precosta	α	37, 38	XVIII
Mesotergite to mesosternite	δ, ϵ	51, 52	XVIIIa
Crossing the pleurosternal line.			
Spiracle to precosta	1	39	5b
Propleurite to precosta	m(sometimes)	42	5b
	q(rarely)	40, 41	
Mesotergite to parts of leg	β, γ	46–50	5α, 5β
Short posterior muscles	ζ, y	33–34	XVIII
Below the pleurosternal line.			
Behind precosta	q, m	40,41(42)	5bα
Across leg in front	n	43	6α
Across leg behind (from ψ)	r	53–54	6β
From fold or ψ to leg	γ(part)		6aα
From fold or ψ to anterior edge of following segment	ζ(part)	31–32	
	z	55	XVIIIβ?

NOTES: (1) 1aβ in most forms, not distinct from V in *Cossus*, I on legless segments
(2) The fibre of θ which runs between the precostae is marked 4 on the plates; it is not well defined in *Cossus or Sphecodina*. Fibres of θ proper spread fan-like from the acrosternite to various points in the acro- and protergites.
(3) To antecosta of following segment in *Phœocyma*.
(4) From acrosternite in *Phœocyma*.

The muscles which attach to the ends of the segments are sharply divided into two groups, in the first, comprised of A, B, C, E, a, b, c, d, the muscles of successive segments are united, forming a single polygastric muscle, the remainder are so inserted to leave a distinct space between muscles of successive segments. In the case of D and i, the distinction is striking, as compared with A and a respectively.

NERVES.

There are three pair of nerves from each abdominal ganglion. The principal or anterior one runs almost directly out from the anterior half of the ganglion, passing over all the muscles near the midventral line, but soon plunging in (between a and c) and running between the layers up to the subdorsal region, where it ends in a longitudinal fibre, perhaps the chordotonal organ. It supplies but little of the skin, but sends off numerous branches to the muscles, especially the larger segmental ones. The second or posterior pair of nerves runs obliquely downward under i, passes between k and p, often forming the only distinction between these two muscles, and then ramifies in the crowd of short muscles connected with the proleg, and on the skin. The third runs directly back as a single nerve from the posterior end of the ganglion under the fused connectives,

until they separate, then forks, in the substance of the very slightly developed ventral diaphragm and runs out, often along the incisure, to the spiracle and from there to the tip of the wing of the heart; no muscles overlie its main stem, but it sends down branches to anastomose with the second nerve, and connects with the anterior one in the neighborhood of the spiracle. It certainly supplies the spiracle and probably some muscles, but on account of the anastomoses it is impossible to be sure. Sometimes the fusion of the connectives is complete, as in Sphecodina (Plate 5) and this nerve seems to arise from the anterior end of the ganglion after the one to which it belongs. In the thorax its connections are always perfectly clear, because of the wide separation of the connectives.

On the third to sixth segments the structure is identical, as described, except for purely individual variation, but the others show various stages of reduction.

OTHER SEGMENTS OF THE ABDOMEN.

The *second segment* differs only in the reduction of the muscles of the proleg, and the loss of a couple of fibres, but they do not change their points of insertion. x is insignificant or absent; k and p are usually unchanged, but may appear as short parallel oblique fibres evidently homologous to I and L dorsally. This condition appeared in an odd specimen of Malacosoma disstria. γ, m, n, q and r are reduced in strength, but not notably changed in points of insertion.

In the *first segment* the proleg is so reduced as to be unrecognizeable, in a stage corresponding to Berlese's Fig. 477 D, which was evidently prepared from the seventh segment. The fat pad, which causes the proleg of the second segment to keep nearly its normal relations, is unimportant here, and the transverse fibres (of the l, q group) are shortened. β, (representing γ) is merely a couple of fine fibres which barely cross the fold. The antecosta dorsally and precosta ventrally are also not developed and the muscles which normally end in them are continued to the front of the segment; these are a, i, E and f′ when present. As the trunk trachea disappears at the first spiracle α is not distinguished from θ, whose fibres are crossed as a result of the moving forward of E and F. H, however, may remain unchanged, and the spiracle is only

a little in front of its usual position. The innermost fibres of c nearly meet in the middle line, covering the origin of a.

Toward the posterior end reduction is progressive to the last segment, and becomes extreme in the ninth, which however, is unmistakably a true segment. The fibres gradually go over to the rectus type, becoming simple and longitudinal, and gradually decrease in number, till in the ninth segment only five ventral ones are left.

The ganglia are fused in the *seventh segment* more or less completely, but always the true seventh ganglion is recognizable with its usual nerves,—,the sympathetic nerves from the last spiracle run back united with the nerve for the eighth, as far as the incisure, then run normally to the spiracle and last wings of the heart. All the principal muscles are present, but a, f, g, h, i and E do not extend beyond the eighth acrosternite, because of the disappearance of the pre and ante-costa of the eighth segment. The deep muscles are reduced, p and x appear clearly as longitudinal (oblique) muscles similar in character to I, L and Q, R of the dorsal region. ζ also appears longitudinal, a suggestive fact, as in general it resembles more closely the fanlike transverse muscles, but z is evidently transverse. α is normal, m and q are undifferentiated, and clearly pleurosternal; d is normal, n and r extraordinarily shortened, while β (representing γ) and δ are also nearly simple—evidently the proleg is merely the small area enclosed by n and r.

The *eighth segment* has the two normal nerves running back from its ganglion in the preceding segment. The first runs outside c, which apparently represents part of a of other segments; it passes between f and g, defining them as usual. Muscles a to i and the corresponding dorsal ones are all reduced to the simple segmental type, M and l, being connected with the spiracle, remain normal, but θ is simplified in front and its homologue behind is much reduced. The lateral muscles are perfectly simple, and the longitudinal ventral ones are reduced to a single set of sort fibres (p).

In the *ninth segment* with the disappearance of heart and spiracle the sympathetic is also gone, but the two principal nerves are easily found, (sometimes with the first arising behind the second). The first runs between a and b, which latter has to serve for b, c, d, e, f, ff, and h of normal segments;

e probably represents normal g, while d would be a transverse fibre. The odd fibre e' may be the last trace of the proleg. The posterior nerve, with the disappearance of the proleg, runs mainly to the skin.

The *last segment* is specialized to such an extent that an embryological study would be necessary to straighten it out. It doubtless is a fusion of at least two. Its one large nerve runs mainly to the proleg and on its way serves as a stalk for the nerves of the preceding joint.

COMPARATIVE ANATOMY.

Including this paper I can find only five widely separated families represented by dissections of the muscular system, namely:

COSSIDÆ; *Cossus cossus* by Lyonet.

NOTODONTIDÆ; *Pygæra bucephala* by Lubbock.

LASIOCAMPIDÆ; *Malacosoma americana* and *disstria* in this paper.

NOCTUDIDÆ; Two species, probably of *Noctua* and *Nephelodes*, both trifidæ and a *Phæocyma* (quadrifidæ) in this paper.

SPHINGIDÆ; *Delilephila lineata*, briefly by Berlese; and *Sphecodina abbotii* in this paper.

These few species indicate, however, that the characters of the muscles are likely to be as well marked as of any other part; the following points stand out most strikingly:

In the *Sphingidæ* the muscles, especially the large ones, tend to be broken up secondarily into a considerable number of fibres. This shows strikingly in the recti. Q and R show a variety of lengths and tend to run to at least two secondary annulets; x and p cross the middle line and interlace with each other. Well marked resemblances to Cossus appear in the broad convergent and overlapping e and ff, in the filling of the body cavity with tracheæ, and the slight differentiation of 4. The thoracic muscles are particularly massive; the longitudinal connectives are fused unusually far in the thorax, and completely in the abdomen, throwing the apparent origin of the sympathetic fibres back to the ganglion of the next segment.

The *Cossidæ* show their primitive character in the well separated ganglia in the seventh segment, the slight differentiation of 4, the fact that x is nearly longitudinal and hardly distinct from t, even in the segments with prolegs, and the well developed ninth segment of the abdomen.

The *Lasiocampidæ*, like the Sphingidæ, show a tendency to increase of muscles, but it is slight. The deeper transverse fibres alone become numerous and unstable; they are weak and altogether much as one would expect in a form which had passed through a lappet-bearing stage and was degenerating. It is not unlikely that such a larva as Epicnaptera will show a strong and highly specialized lateral system. The differences between the two species is slight, in the first segment *disstria* has only three, *americana* usually five ventral rectus muscles; the lappets are much distincter in *disstria*, but not really functional, so that the difference is not noticeably reflected in the muscles. As a whole the genus is characterized by the massive upper fibre of ζ, a suggestive character in a lappet-bearing family, and the frequent presence of the aberrant fibre f' (as figured) in both species. In the eighth segment there is a large tracheal tuft, which may serve as a sort of lung to aerate the blood where it first enters the heart.

The *Noctuidæ* are marked by their simple and normal condition, without the primitive points of Cossus or the specializations of the others, and are closely similar to each other. p and x meet on the middle line, but do not cross, as in Cossus. In general they are much like Cossus, but possess 4, and p'. The tracheæ are reduced and inconspicuous. Of the two species the Noctua had slenderer lighter muscles. The insertion of p along the midventral line is a little different in character, and as it leaves its trace on the skin may prove a help in identifying in this difficult group.

A Catocaline caterpillar, apparently a *Phœocyma*, shows a number of interesting specializations, apparently connected with its extraordinary jumping power. The thorax (Plates XVII and XVIII) is normal in general plan, but with various oblique muscles joined end for end into long sets; four pair of these, namely, E, α_1, α_2, and α_3; C^+, L and G; α, C, S and L; and c, f and C extend the whole length of the thorax and there are several other shorter sets, while only the α system of the meso- and metathorax was recognized by Lyonet in *Cossus*. The peculiar breaking up of S in the metathorax at least, caused apparently by the attachment of I through it, does not even occur in other Noctuids, about the mesothorax I am uncertain, as that part of my specimen was damaged in dissection. The principal peculiarities of the abdomen, aside

from those resulting directly from the slender body, are the setension of F to the acrosternite, under α and ζ, the extension of d well into the following segment outside the other ventral muscles and the simplified leg-muscles of A3, correlated with the much reduced proleg; the most noticeable point in this is that while not forming a longitudinal series of transverse fibres as they do in the seventh segment, muscles m and q are represented by a series of several evidently homologous fibres. The nervous system also shows the highest specialization I have seen in a caterpillar; as the first abdominal ganglion is moved forward well into the thorax (Pl. 1, Fig. 1) and the fused last ganglia have also moved forward into the preceding segment and nearly fused with the sixth abdominal. Their nerves, however, are normal, except for the oblique direction.

Lubbock has notes on a few other species in his paper, among them a Pieris.

SUMMARY.

1. Corrosive sublimate produces the most perfect material for dissection of the muscles; four per cent. formalin is more generally satisfactory.
2. The caterpillars should be opened out before hardening.
3. Lyonet's work has proved fully satisfactory, and Lubbock's sufficiently so for almost perfect correlation of the two.
4. The meso- and metathorax are alike, the first eight segments of the abdomen much alike, and capable of general correlation with the thorax.
5. The ninth abdominal segment is much reduced, but an unquestionable segment. It is less reduced in the most generalized form.
6. The first and last segments are of a different type, and probably compound in nature.
7. The first spiracle has moved forward, the second has become rudimentary in situ and the other eight have moved back, but the first rather less than the others. All have the same innervation, in the abdomen largely from the preceding segment.
8. The meso- and metathorax alone have muscles traversing the nerve-cord.

9. The anterior nerve trunk divides the longitudinal muscles into superficial and deep sets, and the longitudinal trachea similarly divides the transverse ones.

10. The antecosta and ventral precosta arise as specializations of the acrosternal insertions of the muscles and exist only in specialized segments. The muscles may exist in their absence.

11. Characteristics are pointed out of members of five families and characteristic figures are published of a Noctuid, a Lasiocampid and a Sphingid.

12. The following muscles are differently lettered by Lyonet in the meso- and metathorax.

MESOTHORAX	METATHORAX	MESOTHORAX	METATHORAX
G, H	H only	m	3d belly of α
1st belly of α	G	γ	2nd belly of α
e, f	e only	ϵ	γ
d	f	ζ, φ	ϵ, ζ, φ

It is suggested that his lettering of the metathorax be adopted in general, but that m be used for the posterior of the three muscles he confused as α.

13. The muscle marked E by Lyonet, and IX by Berlese is only a segment in length, both terminations being on the antecosta.

14. Cases occur of wide shifts in the origin and insertion of muscles, both relative and absolute, notably in the primitively longitudinal ones p, p', and x, near the midventral line and in d and F of Phaeocyma; they should therefore be used with a good deal of caution in identifying sclerites or parts of the body, at least where as in the caterpillars the sclerites are obsolescent.

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A complete monograph of caterpillar structure based on *Cossus cossus*, (family *Cossidæ*) with numerous engraved plates, illustrating, among other things, the entire muscular system and its nerve-supply.

LUBBOCK, J.: Arrangement of cutaneous muscles of the larvæ of *Pygaera bucephala*. London, 1858.
Family Notodontidæ.

BERLESE, ANTONIO: Gli Insetti; Milano, 1909.
A long chapter on insect muscles and their homologies, with figures of *Deilephila* (*Sphingidæ*) and numerous non-Lepidopterous insects.

EXPLANATION OF FIGURES.

Plates XVII and XVIII—Dissection of the thoracic muscles of *Phaeocyma* sp., following Lyonet's lettering, and nearly following his order of dissection. The muscles not hatched, which appear in the various layers are those which appear more distinctly in succeeding ones. The dorsum of the mesothorax, and the prothorax, especially in front are incomplete.

oes. suboesophageal ganglion.
gang. T^1. First thoracic ganglion.
gang. T^2. Second thoracic ganglion.
gang. A^1. First abdominal ganglion. The ganglion of the metathorax lies near the letter c of that segment, under the muscles c.
tr. Functional trunk-trachea of the thorax.
sp. A^1. First abdominal spiracle.
D, A, B and E at the lower edge of Fig. 1, and E on Fig. 2, belong to abdominal muscles, the latter extending forward well into the thorax.
Rudimentary crossed muscles are shown in Fig. 1, overlying the prothoracic ganglion.
In Fig. 6 the stippled areas represent the position of the wings; they underlie all the muscles except the long fibres of T and w.
sp. in Fig. 6 is the rudimentary second thoracic spiracle, in Figs. 4 and 5 π indicates its trachea.

In this and most of the other figures the musculature is shown as it appears when the caterpillar is opened and spread out, the muscles nearest the body cavity appearing superficial, and the last layer of dissection representing the ones close to the skin. In this figure the head was cut in several pieces to enable the prothorax to be spread out flat, and the broken lines represent the mid-dorsal and midventral lines, marked by the position of the dorsal vessel and nerve cord. The small muscles of the legs are not shown.

Plate XIX.—Metathorax of *Noctua baja* (?), dissected in six stages, following approximately Lyonet's directions and using his lettering.

gang. Ganglion.
sy. Fork of sympathetic nerve.
π. Rudiment of middle thoracic spiracle and its trachea.
im. Rudiment of an imaginal muscle.
The wing is shown in the deepest dissection and coarsely dotted.

Plate XX—The middle abdominal segments of *Nephelodes minians* (?) similarly dissected in six stages, in the following order:

1, 2,
4, 3,
5, 6.

Plate XXI—Middle segments of *Sphecodina abbotii*, dissected in the same order, in four layers.

tr. Trachea.

Plate XXII—Middle segments of *Malacosoma americana* dissected in four layers in the following order:

2, 1,
3, 4.

d. v. Dorsal vessel or heart.
w. h. wings of the heart.
sp. Spiracle.
tr. trachea.
gang. Ganglion.
sy. Fork of sympathetic nerve (belonging to preceding segment).
The position of the hooks of the proleg is indicated by a series of bars.
5 is a small muscle in the planta.

Plate XXIII—First two layers of muscles of the first two segments of the abdomen of *Malacosoma americana*, the first layer on the right.

In all the preceding dissections the caterpillar is represented as if opened on the dorsal line and spread out flat, so that the mid-dorsum is divided between the two edges and the midventral line lies in the middle.

Plate XXIV—Ventral musclature of the posterior segments of *Sphecodina abbotii*. The left side is shown as seen from the inner side. 1, as seen when opened and spread out; 2, after removing the muscles hatched in Fig. 1; and 3, similarly after removing those hatched in Fig. 2. The principal nerves are shown as wavy black lines; the segments are numbered and their boundaries indicated in Fig. 1 by arrows.

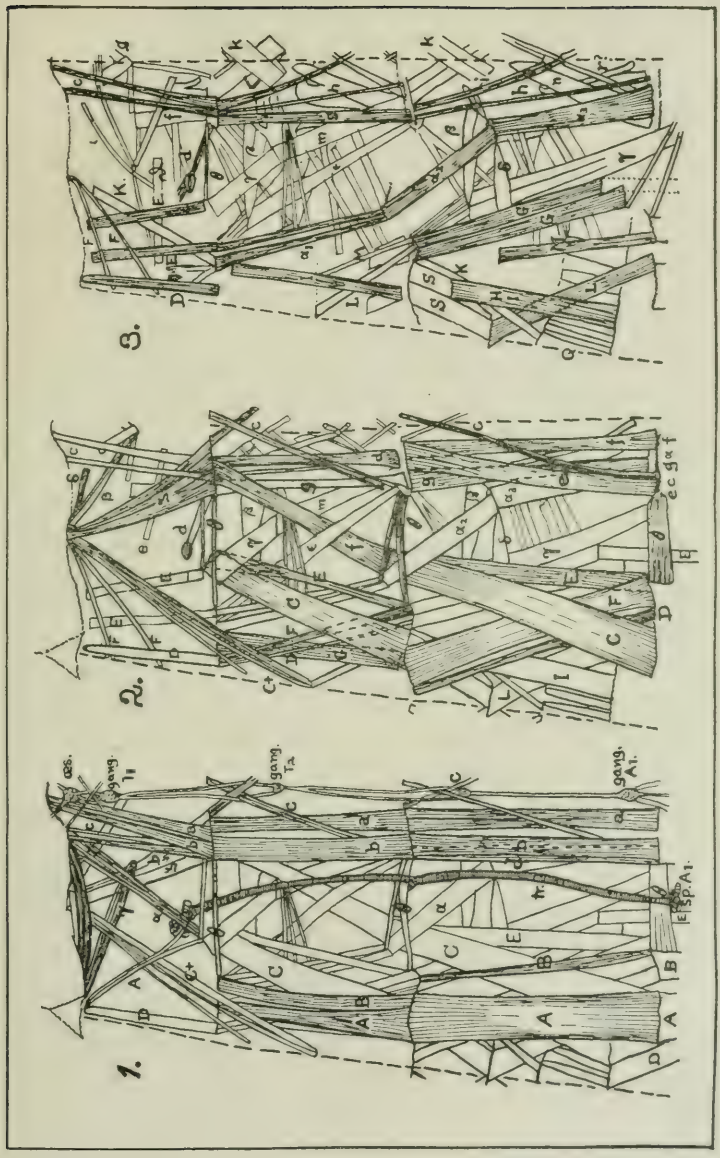
Plate XXV—Diagrams of segment.

Fig. 1. An abdominal segment (left half) spread out and with the principal annulets and regions labelled, modified after Berlese.
ACRO. acrotergite.
PRO. protergite.
MESO. mesotergite.
META. metatergite.
The four sternites are similarly placed.
sp. spiracle.
ap. tergostern. tergosternal apodeme, pleurosternal suture, or subventral fold.
ante. antecosta (ventral end).
pre. precosta.
inter- intercosta.
pl. planta of proleg.
φ, ψ. Minor apodemes.
ω. ringlike folds, considered by Berlese to mark rudimentary segments of the leg.

Fig. 2. A similar diagram of the metathorax, as developed, e. g. in Sphecodina.
w. Wing-bud, marking the upper boundary of the pleurites.
pleur. pleurite, its boundaries indicated by arrowheads.
m. cx. membranous part of coxa.
ch. cx. chitinized part of coxa.
ACRO, PRO, MESO. and META., as in Fig. 1.

Fig. 3. A superposition diagram of the muscles of the metathorax as seen from within. Each muscle is represented by a double line, interrupted where it passes under another, and the insertions are shown as heavy black bars or dots. The diagram is meant to show the relative position, insertion and direction of action of the muscles, but not their size or form, and is supplementary to Pl. XIX. The rudimentary spiracle and trachea is indicated to the right of the letter θ. Middorsum at left edge, mid-venter at right. c and k, which cross far beyond the middle line, are only partly shown.

Fig. 4. A similar diagram of a middle abdominal segment, serving as an index to Plates 4-6. Dorsally the precosta and intercosta are shown, laterally the antecosta, and ventrally the precosta, pleurosternal suture, apodeme φ (running to the left of the letter ζ) and the oval indicating the boundary of the proleg. The ganglion is dotted, and the anterior nerve indicated as a waved line.



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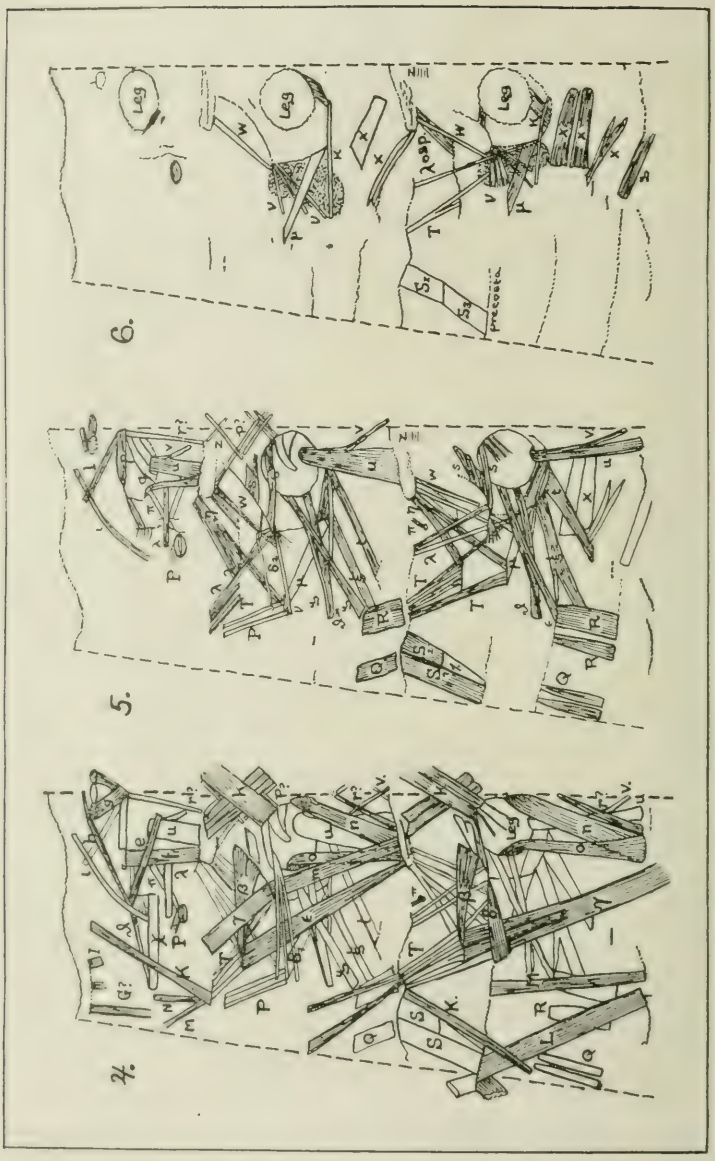

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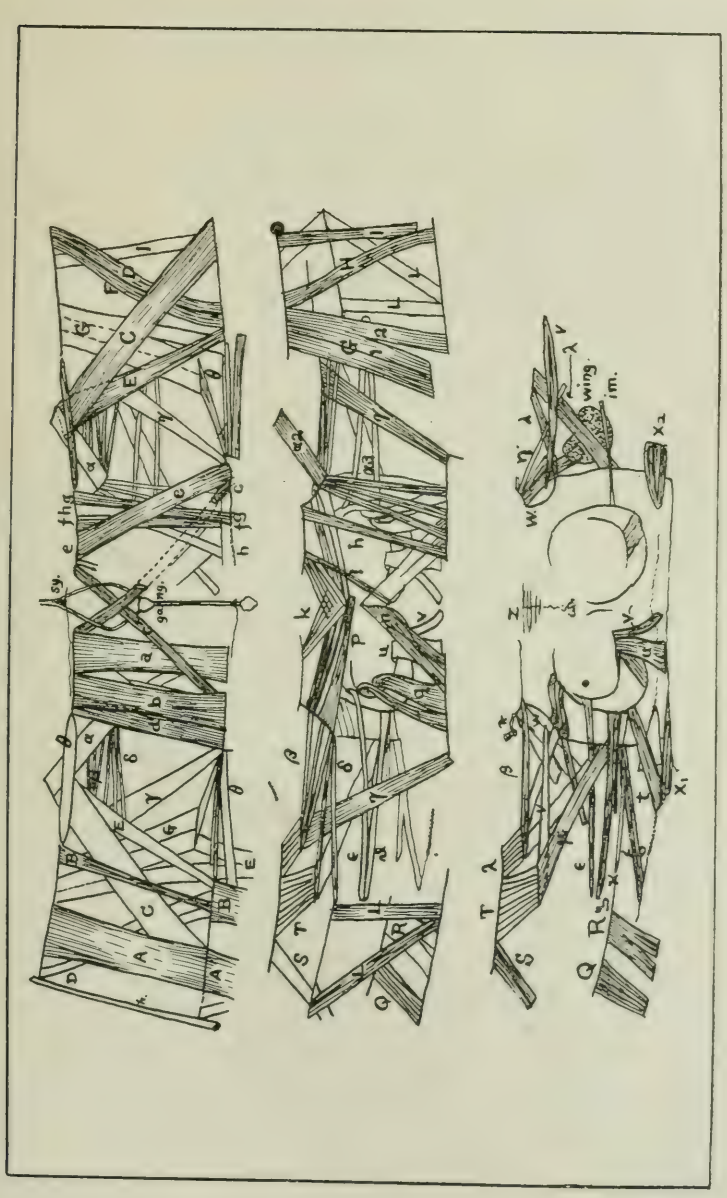

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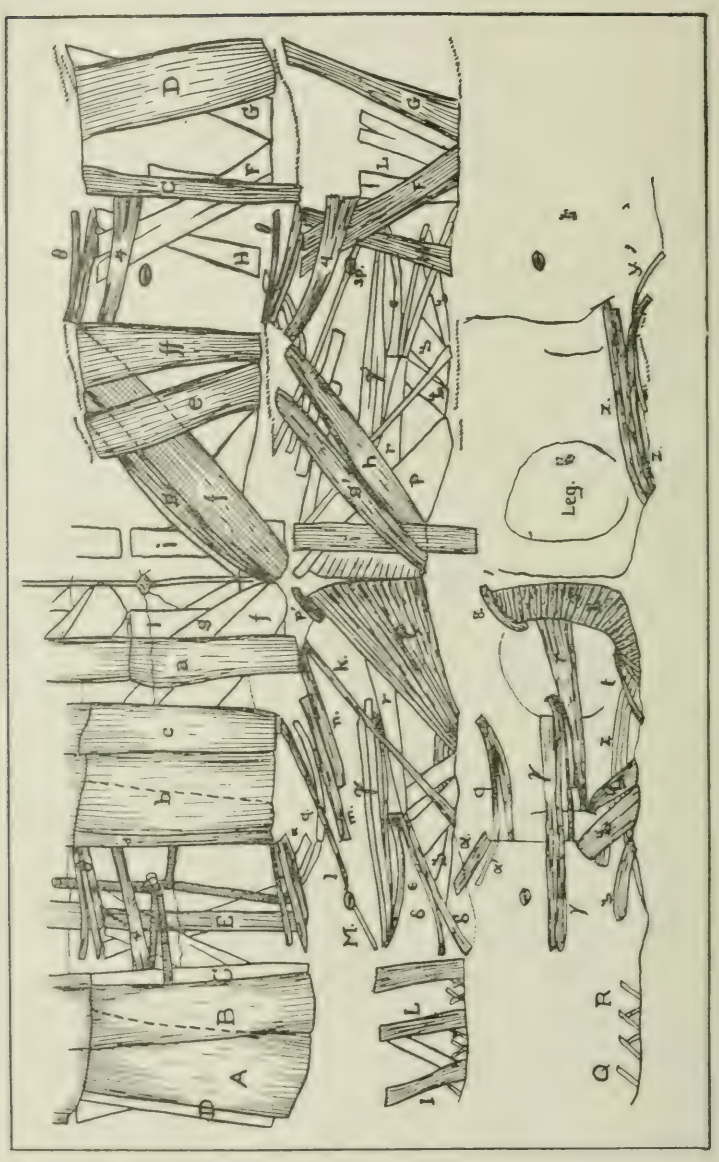

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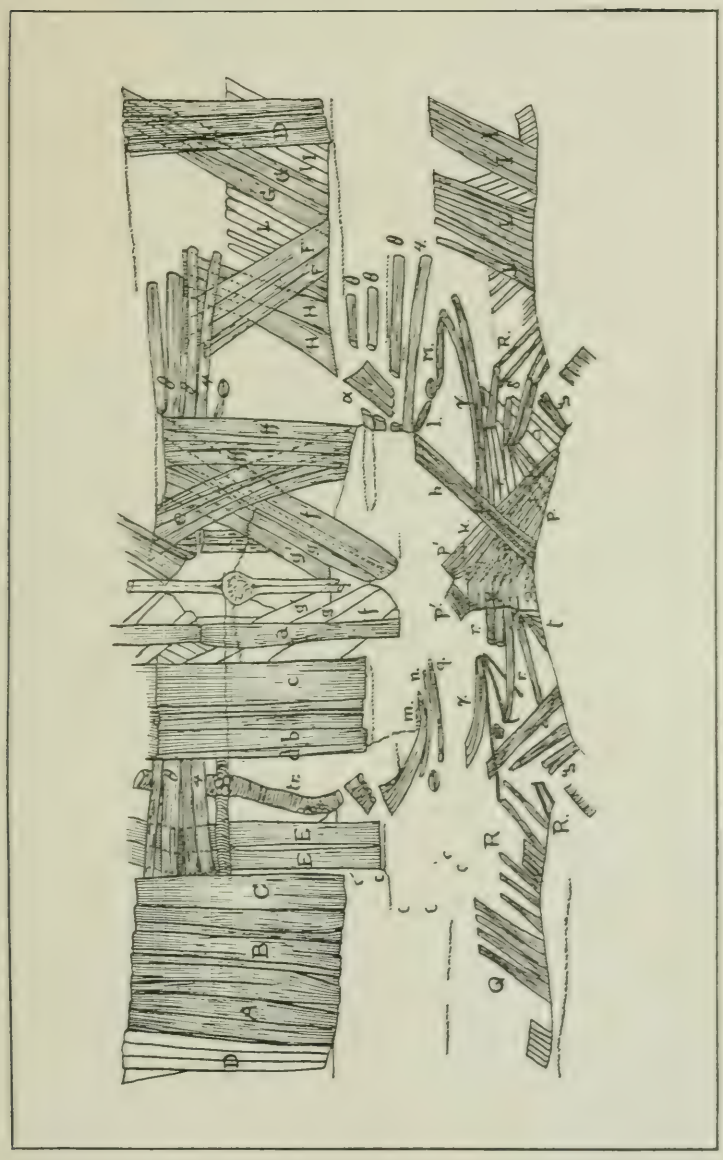
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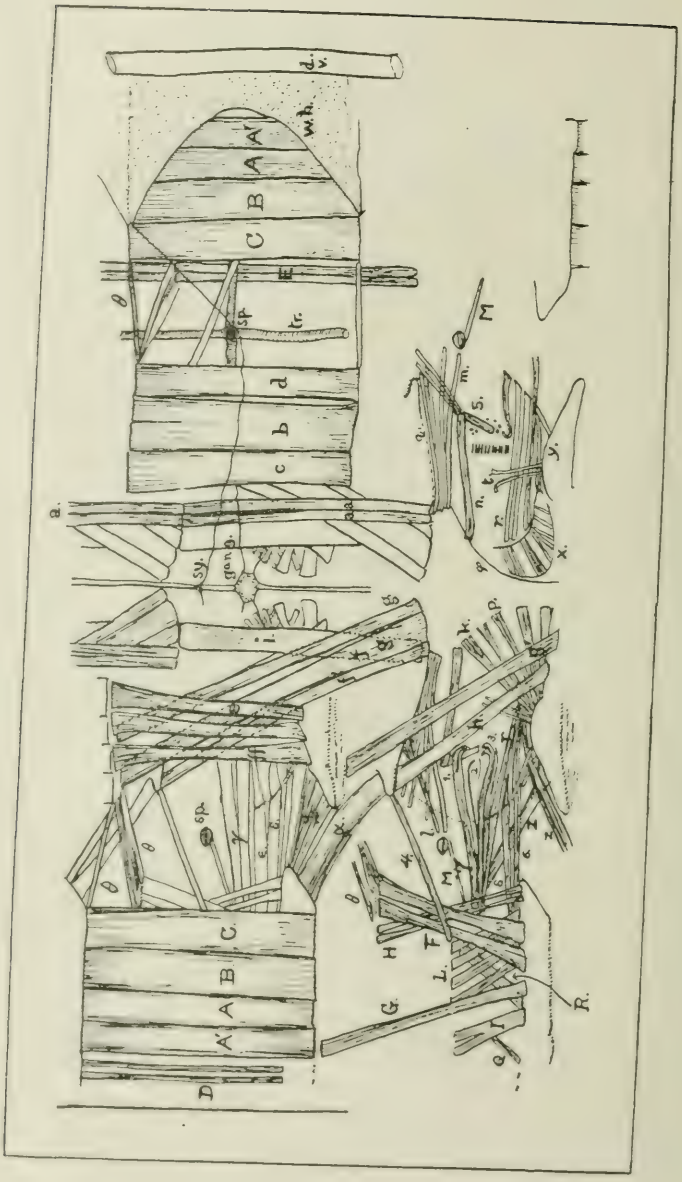
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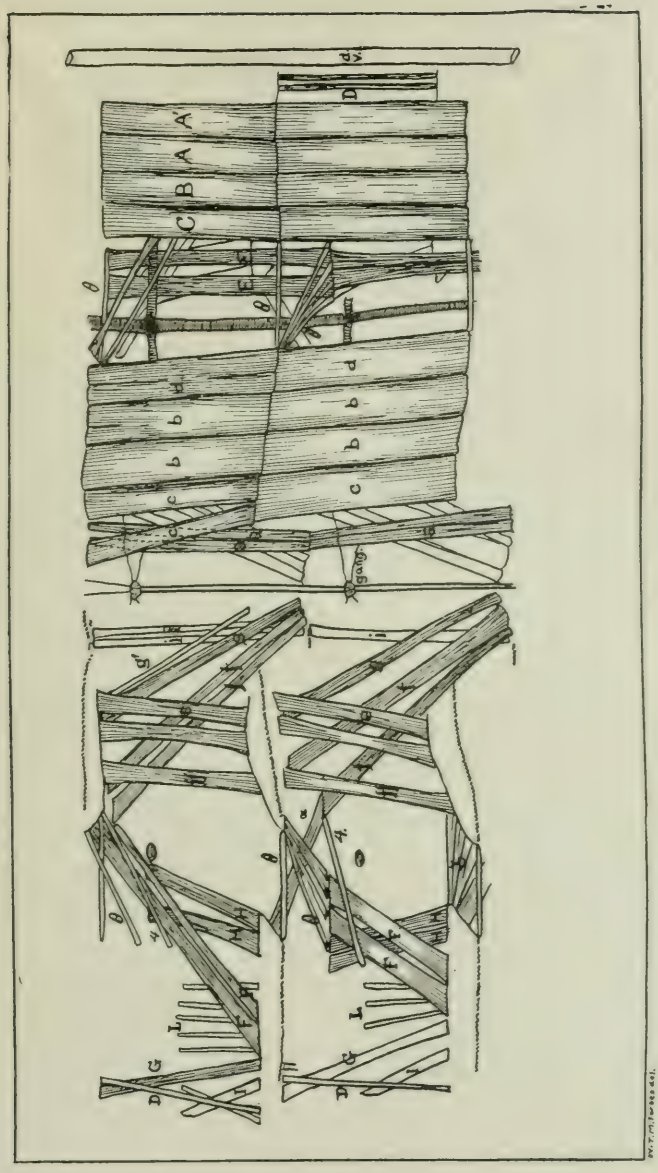

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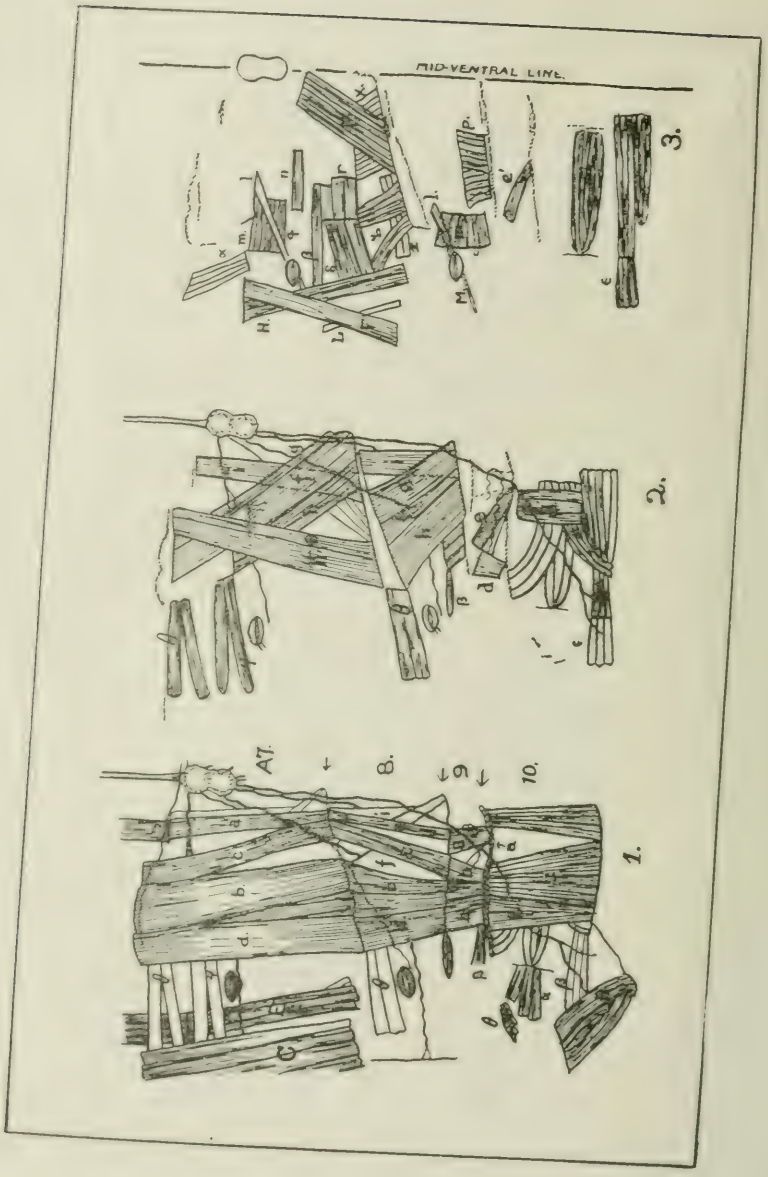

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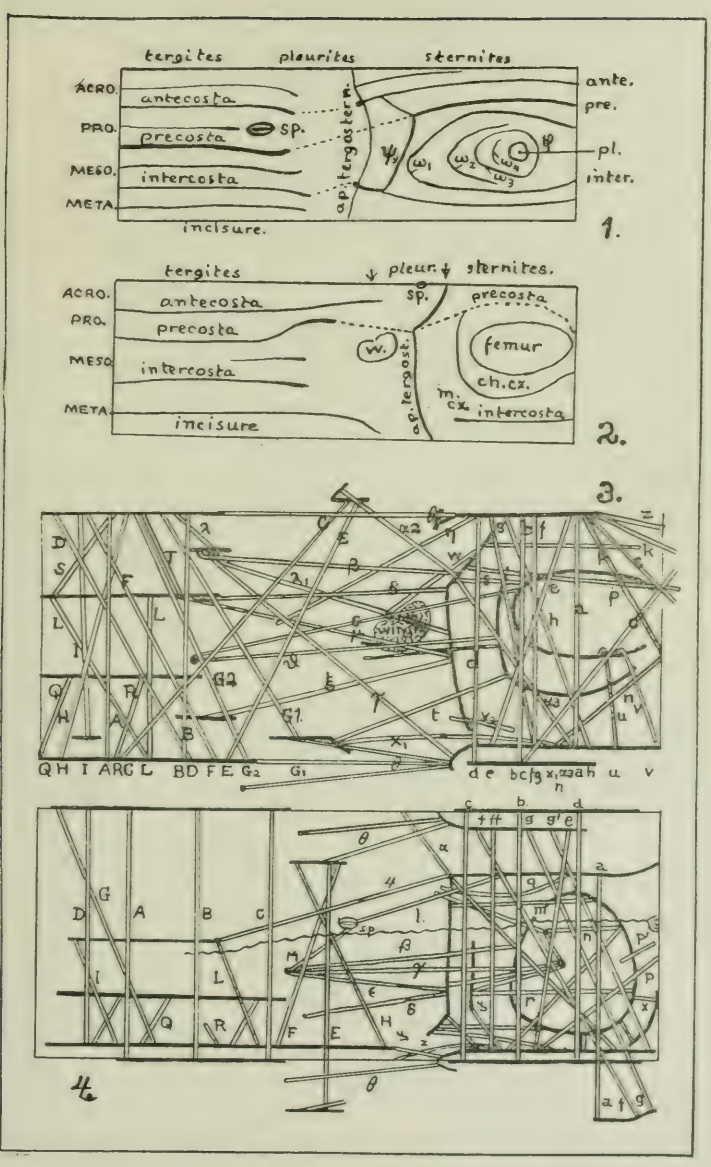
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OBSERVATIONS ON THE LIFE HISTORY AND HABITS OF HYDROMYZA CONFLUENS LOEW., (DIPTERA).*

By Paul S. Welch.

During the past three summers the writer carried on some biological investigations in the vicinity of Douglas Lake, Mich., in the extreme northern end of the southern peninsula of that state. The work was done in connection with the University of Michigan Biological Station, the facilities of which aided materially in securing the data which form the basis of this paper.

Hydromyza, one of the several small genera belonging to the *Cordyluridæ*, has only one species (*H. confluens* Loew) reported for North America. This species is northern in its distribution and seems to have been reported only from New Jersey (Johnson, '04, p. 162) and Michigan (Needham, '08, p. 270). Needham reported it from Walnut Lake, in southeastern Michigan, and predicted that it would probably be found common about *Nymphaea* beds in the United States. In looking over the literature relating to this insect the writer was surprised to discover how little has been written about it. Aside from a brief, two-page paper by Needham ('08, pp 270-271), nothing seems to have been written on the habits or life history of this very interesting insect. It occurred in sufficient numbers to make possible the accumulation of a number of interesting facts relating to this species. The data presented in Needham's brief paper were tested and found to agree with the observations of the writer in almost every respect. Data merely mentioned by Needham have been worked out in more detail and a number of new observations were made. Unfortunately the writer has been unable to observe the method of oviposition and the younger larval stages have not been studied.

THE LARVA.

Food Plant.—Hydromyza confluens was found in connection with the yellow waterlily, *Nymphaea americana*, (Provancher) Miller & Standley. This is the form which has until recently been included under the name *N. advena* or *N.*

* Contribution from the University of Michigan Biological Station, No. 21.

advena variegata, but Miller and Standley ('12, p. 78), have shown that the boreal species has several distinct characters which separate it from the true *advena*, and they have raised Provancher's name, *americana*, to indicate this northern species. *N. americana* occurs in some abundance in the protected bays, in the beach pools, in the mouths of some of the streams, and in sphagnum bogs of the Douglas Lake region and the insects under consideration were correspondingly abundant. Needham ('08, p 270), reported this insect in connection with *Nymphaea advena*, but judging from his description and figures it seems very probable that the species in Walnut Lake was *N. americana*, rather than the true *advena*.

A careful examination of all the aquatic plants occurring in the immediate vicinity of the *Nymphaea* beds was made with the view of determining whether or not other plants were used as food. In no case did the larva occur on plants other than *N. americana*. The white waterlilies (*Castalia odorata*) were entirely exempt in spite of the fact that white and yellow waterlilies mingled in the same beds. In every case the evidence pointed to the conclusion that this insect is restricted to *N. americana* in the region studied.

The Gall.—The immature stages of this insect were found in the long, constantly submerged petioles of the yellow waterlily. A large number of plants were examined and in no case did they occur on any part of the plant other than the petiole. Furthermore they were confined exclusively to certain petioles, namely, those of the floating leaves. Special effort was made to determine whether or not larvæ ever occurred on the peduncles or on the petioles of the submerged leaves. Both were found to be entirely free from infestation. Although the writer has no data on the method of oviposition, the reason for this distribution on the plant seems apparent. Needham ('08, p. 270) suggested that "Probably the attack of the gall maker begins when the first leaves reach the surface in late spring; then they have their first opportunity to reach the proper place of oviposition by crawling down the stalk." The writer regards this as the most feasible explanation since it will be shown later in this paper that it is possible for the adult insect to pass under water by crawling on a supporting surface and that it actually does so of its own volition. The short and wholly submerged leaves of *N. americana* do not at any time

reach the surface and since this is true there would be no opportunity for the female to deposit the eggs, hence the constant freedom from infestation. Furthermore, in the region of Douglas Lake, the flowers do not reach the surface of the water until in late July and in August, a date which is much later than the time of oviposition, and as a consequence they are exempt from the attacks of the insect.

The gall first becomes perceptible on the petiole as a slight, ovoid enlargement and can be detected by pulling the petiole between the fingers. Each gall is produced by one larva only and in no case is more than one larva found in a single gall. It is very probable that in the early stages the presence of the larva is not perceptible since this enlargement really occurs at a time when the larva is well toward maturity. As the time of pupation approaches the gall begins to turn brown, ultimately assuming a deep brown color, thus making it easy to detect. The shape of the exterior of the mature gall varies somewhat, usually appearing as an ovoid swelling, although it should be noted here that many of the galls do not increase the diameter of the petiole. The galls also vary in size to some extent, the length of those containing pupæ ranging from 6 to 9 mm. They are always longer than broad, the long dimension being in the direction of the long axis of the petiole.

The number of galls per petiole varies rather widely. Sometimes only one gall occurs on a petiole, but usually the number is greater. In a large series of observations the maximum number on a single petiole was found to be 14 and many of the petioles contained as high as 13. In one of the series of counts in which 45 infested petioles were examined, 7 was found to be the average number of galls per petiole. No relation was found to exist between the length of the petiole and the number of galls. It might be assumed that the longer petioles contain the larger number of galls, but this was not always true. Numerous instances were observed in which a petiole, six feet in length contained only two or three galls, while a neighboring petiole, three feet in length, contained 10–12.

Galls occur irregularly along the petiole and may be situated near the bottom, even in those almost six feet long. They may be distributed along the entire length of the petiole and well

separated from each other, or they may be distributed in such a way that some are widely separated and others so closely placed that two or three may appear to be continuous.

The interior of galls containing pupæ, or half to full-grown larvæ, can be easily examined by removing the infested petiole from the water and holding it between the eye and the light. The cavities are not at all uniform in shape. Each has a slightly elongated central chamber and one or more side channels which are usually just large enough to contain the larva. The total space in the gall of a full grown larva is commonly three or four times as large as the larva itself. The size of the cavity represents the bulk of the food which the larva has consumed during its growth and since there is no connection with the exterior all of the excrement is deposited within the gall. The consumed matter, as indicated by the amount of excrement, does not seem to decrease much in bulk so that near the time of pupation the greater part of the gall is filled with a brown excreta which almost surrounds the insect. This brown excrement has much to do with the brown exterior which characterises these excrescences and renders them conspicuous.

The full-grown Larva.—The morphological details of the full-grown larva will be included in a future paper which is in preparation. Needham's paper contains a very brief description of the larva and presents some of the more important anatomical details.

Variation in Maturity.—An examination of the galls on a given petiole often showed differences in the degree of maturity and when the larvæ on such a petiole were extracted and examined it was found that they too were not all exactly of the same degree of maturity. In some cases part of the number had pupated while others on the same petiole were still in the active larval stage. It thus appears that some of the larvæ lag behind the others in development and the question arises as to how this fact is to be interpreted. It is conceivable that this might result from the deposition of eggs at different times by different females, but the writer, after examining a large number of such cases, is skeptical of such a possible interpretation and believes that in the majority of cases at least, all of the galls of a given petiole are the result of eggs laid at one time since, (1) although some of the larvæ lagged

behind others in development, the differences did not seem to be sufficiently marked to warrant the conclusion that the eggs were deposited at different times, and (2) in some cases those lagging behind occurred in the middle of the petiole, while those towards the upper and lower extremities of the petiole developed at the same time, a condition which would not be likely to happen in case the eggs were laid by different females. The above evidence is not entirely conclusive but it seems to support the more feasible explanation, namely, that the eggs on a petiole are all laid at one time, and that the variation in the degree of development is possibly due to internal or external factors, probably the former since the external conditions seem perfectly uniform for all those deposited on a given petiole.

Activity.—Like many other dipterous larvæ, this gall maker is very sluggish. Specimens, removed from galls, showed only slow, squirming movements which were very ineffective so far as locomotion was concerned. The activities of these larvæ could be observed to some extent by holding an infested petiole between the eye and the source of light. The feeding activities appeared to be very deliberate.

Effect on the food plant.—As mentioned above, the first evidence of infestation is the presence of a slight, ovoid swelling at various places along the petiole. Later these swellings begin to develop a brownish color, ultimately becoming a deep brown. About this time or a little later the entire petiole loses its green color, takes on a yellow appearance, and shortly afterwards the entire leaf begins to turn yellow, showing signs of deterioration. During the last week in July and the first week in August of 1913 one could readily pick out the infested lilies by the yellowish leaves. This work of the larvæ leads to the decay of both leaf and petiole. The nature of the injury is simple. The larvæ affect the plant in two different ways: (1) The larva, as it eats out the internal cavity of the gall, severs the vessels which connect the leaf with the root-stalk, this alone being sufficient cause for the decay of the leaves. It was found that the heavily infested petioles deteriorated no more rapidly than did the slightly infested ones and that one larva is just as efficient as several in causing the death of the leaf. (2) These galls produce weak spots in the petioles so that wave action breaks them at the points of

infestation. Leaves with broken petioles were found floating about early in the season before the galls had begun to turn yellow, but the greatest havoc from this cause was produced during the first week of August of the past year when the larvæ were pupating. At this time in one of the badly infested lily beds approximately 40% of the leaves were broken off and were floating about in a semi-decayed condition.

The possibility of other insects playing a part in causing this deterioration of the petioles and the change in the color of the leaves was taken into account and, while other enemies were present, it was possible to observe many leaves and petioles which were infested only by the larva of *H. confluens* and which showed the same effects as those which happened to be affected by more than one enemy.

All of the lily beds in the immediate vicinity of Douglas Lake were examined and the degree of infestation observed. There was considerable variation in this respect since some were only slightly infested while in others the percentage of infestation was as high as 50 or 60. None were entirely exempt. It was found that the heaviest infestation occurred in a lily bed which was located at the end of a point which formed one side of a protected bay and was thus exposed to the wind and wave action to a greater extent than any of the other lily beds. In this particular case the infestation was almost twice as great in this exposed lily bed as in another in the protected bay only about one hundred feet away. The infestation in the lily beds in the beach pools and the sphagum bogs, which are protected from the action of the wind and waves, was very slight. The writer is not prepared at the present time to account for this distribution, but merely gives the facts for this particular region, realizing that the distribution just described may not agree with that of other regions.

It thus appears that the larva of *Hydromyza confluens* is a serious enemy to *Nymphaea americana* since every petiole which contains even one larva is doomed. Three summers of work on insects infesting waterlilies in the Douglas Lake region has convinced the writer that, although there is a rather large number of species which attack this plant, yet *Hydromyza confluens* has only one rival for first place as the greatest enemy namely, the larvæ of *Bellura melanopyga*, one of the *Noctuidæ*, which also plays havoc in the lily beds.

THE PUPA.

The detailed description of this stage is reserved for another paper which is in preparation.

Position.—The position of the pupa in the gall is variable, the only constant feature being the fact that its long axis always lies almost or quite parallel to the long axis of the petiole. However, the position of the head and the caudal end is not at all constant since in some cases the head is up (towards the surface) and in others it is down (towards the root-stalk). In galls which are well advanced in development and contain pupæ this point can easily be determined from the exterior without breaking into the gall by noting the position of the *window*, a feature to be described later. When the window occurs at the lower end of the gall it is positive proof that the head of the full-grown larva or the head of the pupa is down; if the window is at the upper part of the gall, the head of the larva or pupa is up. In a series of observations in which 242 pupæ were examined it was found that 130 occupied a position in which the head of each was up and 112 in which the head of each was down. Other statistics of the same kind showed a similar result, namely, that the majority of the pupæ lie in the galls with the head towards the surface of the water.

The Window.—The window mentioned in the preceding paragraph is a very interesting and unique provision for the emergence of the adult and, as stated by Needham, is constructed by the larva immediately before pupation. It is circular in outline and only large enough to allow the passage of the emerging adult. In constructing this window the full-grown larva works towards the exterior of the petiole until it reaches the epidermis. Here it removes all of the surrounding tissue (exclusive of the epidermis) from a circular area which is destined to be the window so that the latter is composed only of epidermis. A circular incision, which extends around approximately two thirds of the circumference, is made along the periphery of this area. The remaining one-third is left intact and thus a circular lid, attached at one side, is produced. The attached portion always has a definite relation to the position of the pupa, namely, it is constantly on the side of

the circumference nearest the caudal end of the pupa. The larva evidently constructs this circular incision by rotating the head through about 240 degrees, cutting the epidermis with the mandibles as it goes. Needham ('08, p. 270) in discussing this matter makes the following statement: "Just before transformation to the pupal stage the larva eats a hole out to the epidermis and returns to the center of the cavity; this hole is a passage of exit for the adult, which then has only to break through the transparent epidermal window to gain its liberty." One would infer from this statement that the window is opened at the time of the emergence of the adult by the rupture of the epidermis, but this is not the case. Also no mention is made of the fact that the epidermis is cut in any way. The evidence is conclusive that the operation of opening the window is not a mere rupture of the epidermal tissue since: (1) Very careful examination shows that a circular incision is actually made and that the translucent window is merely pushed open at emergence, (2) it is an easy matter to open one of these windows on a gall from which the adult has not emerged by either carefully inserting the point of a needle between the edges of the incision, or by splitting the gall and applying very slight pressure against the inside of the window, which in either case opens as a hinged shutter with the attachment constant in position, and (3) an examination of a large number of petioles from which the adults had emerged showed that in every case the window opened as a hinged shutter, the attachment of which always had the above described, definite relation to the body of the gall and to the pupa. If the opening of the window was a matter of rupturing the epidermis there would be no possibility of this constancy in the form of the opened window. It should be mentioned in this connection that the incision is not an absolutely continuous one, since a few minute portions of the tissue are left uncut and serve to hold the window closed up to the time of emergence. It is therefore possible, under average conditions, to determine from the exterior whether or not the adult has emerged. If the window is not loose around the edges the insect is still within the gall, but if the window is loose and gapes slightly it is very strong evidence that the adult has emerged. An exception to this rule may occur in a petiole

which has been subjected to side to side strains such, as are produced by wave action, and the window has thus been broken open.

According to the observations of the writer, pupation occurs shortly after the window is completed and the pupa lies with the cephalic end in close proximity to the window. In some cases the pupa lay so close to the window that the movements of the adult in escaping from the puparium would have been sufficient to open it.

One of the characteristics of *Nymphaea americana* is the shape of the petiole. It is conspicuously flattened so that approximately one-third of the circumference is quite flat while the remaining two-thirds are very convex. For convenience in discussion these surfaces will be designated as the plane surface and the convex surface. On the former there is a median, longitudinal ridge. Needham's paper indicates nothing as to constancy or variation in the position of the window with reference to the two above-mentioned surfaces although he figures a gall with the window on the convex surface. The position of this window is variable, sometimes occurring on the plane surface and sometimes on the convex, but not in equal numbers and the writer was lead to make some observations on this point. Of 226 galls examined at random the window in 137 occurred on the convex side and in the remaining 51 cases on the plane surface. Various other counts not recorded in the above numbers showed similar results. Available data does not seem to offer an explanation for the predominance of the windows on the convex surface.

THE ADULT.

Broods.—Although the writer has no positive evidence as to the number of broods per summer, there seems to be the possibility of at least two. A few adults were observed about the *Nymphaea* beds during the first part of July, at least three weeks before the larvæ in the petioles were grown. The maximum appearance of the adults in 1913 occurred between August 1st and 6th. During the period, July 10–25, adults were very rare and it may be that this represents the interval between two successive appearances of the adults. Very few of these insects remained in the pupal stage after August

6th. Adults were very abundant during August 1–6, and it was a common thing to find numbers of them copulating.

Local distribution.—In spite of the fact that these insects have well developed powers of flight they are not found at any great distance from the waterlilies. They occurred ordinarily on the leaves and flowers of these plants and when disturbed made only short flights, seldom taking to open water or to shore. Only in rare instances were flies found resting on plants other than *N. americana.* When undisturbed they assembled in the open flowers or ran restlessly about over the lily leaves, making short flights where leaves were not contiguous.

Relation to water.—These flies are related to the water in several interesting ways. Although the emergence of the adult has not been observed in the field it seems safe to assume that when the adult emerges from the pupal stage it must of necessity push the window open and pass up through the water to the surface, either by crawling up the petiole, or by independent passage through the water, presumably the former. It was found that the flies emerged and came to the surface when the infested petioles of *N. americana* were brought into the laboratory and completely submerged in water. In many cases individuals which develop near the base of the longer petioles must, in emerging, come up through about five feet of water before reaching the surface.

It seems almost certain that the female deposits the eggs by going into the water and crawling down the petiole to the place where the eggs are deposited. Careful watch was kept on adults for periods of an hour or more at a time and none were observed to go beneath the surface in open water. If perchance an individual did alight on the surface it immediately took to wing again. Adults which fell on the surface of the water did not sink, but appeared to be supported mainly by the surface film. The fact that they may and do voluntarily pass under water was demonstrated when the writer observed a few individuals walk over the edge of the lily leaf, go under water, and travel on the lower surface of the leaf for short distances. None were seen to go down the petiole.

Experiments in which adults were submerged showed that under such conditions the flies apparently have a specific gravity less than water, and consequently they rise to the

surface if opportunity affords. They stay below only by clinging to some submerged object. While under water a goodly supply of air clings to them in the form of a dense, silvery coating. When allowed to come to the surface they immediately lose the silvery coating and are apparently as dry as if they had never been in contact with water. Experiments, in which adults were subjected to forced submergence for varying lengths of time, showed that they can remain under water for several minutes without apparent detriment to themselves, due without doubt to the generous coating of air which surrounds them. Submerged individuals usually appeared uneasy and made vigorous effort as if seeking release. The ease with which they apparently resist wetting and the quantity of air which they take below with them make possible the mode of emergence and oviposition suggested above.

Relation to the Yellow Waterlily.—The adults as well as the immature stages have a definite and interesting relation to the yellow waterlilies. This relation will be discussed under two heads, (1) food relation, and (2) possible agents in pollination. Although each of these relations will be treated independently, it will be understood that such separation is purely artificial and also that both are operative at the same time.

(*1*). *Food relation.*—The time of maximum abundance of the adults coincided closely with the opening of the majority of the flowers and it was very evident that the flies were deriving food products from them. Flies swarmed in the newly opened flowers in great numbers, congregating between the petals and the stamens to the extent that often the interior of the flower was black with them. In the case of flowers which had been open only a short time the anthers were crowded in a compact mass under the edge of the expanded stigma or were just beginning to spread out in a radial fashion, while the petals had spread out widely, thus forming a cup-shaped flower and producing a space between the petals and anthers into which the flies crowded. Flowers frequently contained as many as fifty adults. They regularly disposed themselves as described above with the heads in close proximity to the base of the anthers. It often required a distinct shake of the flower stalk to disturb them and this proved to be an easy way to collect adults since one of these flowers could be cautiously thrust into a bottle and the inmates dislodged. This

habit resembles a similar one described by Fulton ('11, p. 300) for certain *Diptera*, the adults of which also congregate in the flowers of a yellow waterlily. Later when the anthers became spread out the flies found better concealment beneath them.

The conspicuous assembling of flies in the flowers is indicative of some rather strong attraction which the latter have for the former and it seems safe to assume that the flies profit therefrom. Nectar is said (Lovell, '02, p. 205) (Robertson, '89, p. 122) to be secreted on the outer faces of the petals in *Nymphaea advena* and it is also probably true of *Nymphaea americana*. Therefore it is possible that the visits of the flies are induced in part by the presence of nectar which forms a source of food supply. Flies were observed in the flowers from the time of opening to the time when the flowering parts began to disappear.

(*2*). *Possible agents in pollination.*—The information that insects are found in connection with yellow waterlilies is not new since species representing several orders have been reported as occurring on these plants by Robertson ('89, pp. 122-123), Lovell ('98, pp. 60-65), Bembower ('11, p. 379) and others. Furthermore Elliot ('96, pp. 117-118) and others claim that flower haunting *Diptera* are of considerable importance in the fertilization of many of the flowers which are visited. It is claimed that *N. advena* may be self- or cross-pollinated (Bembower, '11, p. 379) and this is probably true also of *N. americana*. There is good evidence in support of the view that the insect visitors of yellow waterlilies (*N. advena* and others) may transfer pollen from one flower to another, or from one part to another on the same flower. The writer had occasion to examine large numbers of the adults of *Hydromyza confluens* and it was discovered that many were carrying the pollen of *N. americana*. Swarms of adults taken from flowers in which they had congregated showed that the great majority, and often all, of the insects were dusted with pollen. Very frequently pollen occurred so thickly over the body that the insect was distinctly yellow in appearance. Adults collected August 5-22, showed that pollen was being carried during this entire period. While it was not demonstrated absolutely that these flies carry pollen from one plant to another, the circumstantial evidence seems to point definitely to these insects as being at least one of the factors in the cross-pollination

(and possibly the self-pollination) of *N. americana* and may be summed up as follows: (1) The coincidence of the blooming period of *N. americana* with the maximum appearance of the adults of *Hydromyza confluens;* (2) The large numbers of flies limited in distribution to the immediate vicinity of the lily beds; (3) The assembling of the flies in large numbers within the flowers when the latter have opened sufficiently to admit them; (4) The heavy loads of pollen which are carried by many of the flies and the almost universal presence of varying quantities of pollen on all individuals; (5) The continuous blooming of *N. americana* throughout the greater part of August, so that at any given time there were flowers in all degrees of maturity, a fact which eliminates a difficulty due to the possibility that a given flower is proterogenous; and (6) The behavior of the adults in preferring to pass from place to place by crawling and by very short flights (usually the former when possible) rather than by extended flights, which means a maxium of contact of the insect with the various parts of the supporting plant.

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Department of Entomology, Kansas State Agricultural College, Feb. 26, 1914.

SOME SPECIES OF THE BEE GENUS COELIOXYS.

By J. C. Crawford.

This paper discusses only species occurring in America north of Mexico and no table to separate the males has been included since Prof. T. D. A. Cockerell published a table for this sex in the Canadian Entomologist for June, 1912, pp. 167–170. The key to the females includes all the species for the region under consideration in which the female sex has been described. In the table here presented the characters used for separating *rufitarsis* Sm. from *comstockii* Cress. and *lucrosa* Cress. from *moesta* Cress. are the characters used by Prof. Cockerell in a table to separate the types of the Cressonian species and some non-Cressonian species which he consulted in the collection in Philadelphia. The illustrations were made with a camera lucida, attached to a Zeiss binocular microscope.

1. Last ventral segment not notched laterally, at most emarginate and the part anteriad of the emargination not pointed....2
   Last ventral segment notched, the part anteriad of notch sharply pointed..19
2. Last dorsal segment with the end upturned into a small spicule....3
   Last dorsal segment not upturned at apex....7
3. Last dorsal segment very sparsely punctured at base....**obtusiventris** n. sp.
   Last dorsal segment closely punctured at base....4
4. Punctures of first dorsal abdominal segment separated by less than a punctured width....5
   First dorsal abdominal segment sparsely punctured....6
5. First recurrent vein received by second submarginal cell almost half as far from base as length of first transverse cubital in the ♂ and slightly less in ♀....**gilensis** Ckll.
   First recurrent vein received by second submarginal cell one-third or less as far from base as length of first transverse cubital in ♀ and still less in ♂....**deani** Ckll.
6. Here run **modesta** Sm. and **scitula** Cress., the descriptions affording no points for separation.
7. Last ventral segment towards apex with a long strong fringe of hairs along margin....8
   Last ventral segment not strongly fringed....12
8. Legs black....9
   Legs, except coxae, red....11
9. Last dorsal segment without a median carina or this only indicated at tip....10
   Last dorsal segment with a median carina....**angelica** Ckll.
10. Penultimate ventral segment with small punctures interspersed among the larger ones....**apacheorum** Ckll.
    Penultimate ventral segment without smaller punctures among the others....**alternata** Sm.
11. Fourth antennal joint distinctly longer than third; last ventral segment with subparallel sides and a broadly rounded apex....**texana** Cress.
    Fourth antennal joint hardly longer than third; last ventral segment with the sides converging apically and apex more narrowly rounded. **hunteri** n. sp.

12. Last dorsal segment near apex with two small flattened projections pointed caudad.....**piercei** n. sp.
Last dorsal segment without projections on disk.....13
13. Legs red.....13a
Legs dark.....14
13a. Front at top of inner orbits with a swollen granular area, narrowed centrad and extending to lateral ocelli.....**deplanta** Cress.
Front without such a spot, being coarsely punctured, not different from surrounding area.....**sculptifrons** n. sp.
14. Scutellum strongly triangularly produced, medially almost impunctured. **dolichos** Fox
Scutellum medially closely punctured and not strongly produced.....15
15. Last ventral segment with the sides entire.....**alternata** Cress.
Last ventral segment with the sides emarginate.....16
16. Thorax above with lines of appressed pubescence.....17
Thorax above with only erect hairs.....18
17. "Scutellum medially produced into a tubercle".....**aperta** Cress.
Scutellum medially not produced into a tubercle.....**grindeliae** Ckll.
18. Pubescence white.....**ribis** Ckll.
"Pubescence ochreous; basal part of third abdominal segment more sparsely punctured than in above".....**ribis** var. **kincaidii** Ckll.
19. Clypeus near apex bilobed (viewed from above i. e. not emarginate at apex).....20
Clypeus flat or convex.....21
20. Transverse furrows on segments 2 and 3 deep; punctures on middle of segment 2 basad of furrow close, separated by about a puncture width; arcuate edge of pronotum much more strongly produced, translucent; legs red.....**novomexicana** Ckll.
Transverse furrows on segments 2 and 3 shallow; punctures on middle of segment 2 basad of furrow separated by much more than a puncture width; arcuate edge of pronotum not strongly produced, black; legs with femora usually dark.....**sayi** Robt.
21. Clypeus medially triangularly produced and somewhat reflexed, **banksi** n. sp.
Clypeus apically truncate, gently round, emarginate or tuberculate.....22
22. Basal abdominal segment at least entirely red.....23
Basal abdominal segment black (at most with sides red).....25
23. Scutellum sparsely punctured, somewhat produced medially and slightly reflexed.....**menthae** Ckll.
Scutellum closely punctured.....24
24. Abdominal segments 1-3 red; wings, except extreme bases dusky, **slossoni** Vier.
Segment 1, only, red; wings with only apical part dusky, **slossoni** var. **arenicola** n. var.
25. Legs red.....26
Legs, at least femora, dark.....31
26. Scutellum with a strong median projection.....**germana** Cress.
Scutellum medially at most tuberculate.....27
27. Third joint of antennæ hardly longer than second, about half as long as fourth.....**asteris** n. sp.
Third joint of antennæ distinctly longer than second, almost as long as fourth.....28
28. Last dorsal segment narrowed at almost a right angle; first abdominal segment closely punctured laterally.....**coquilletti** n. sp.
Last dorsal segment not narrowed at almost a right angle, at most at a very obtuse angle.....29
29. Last ventral segment very narrow, strongly bent downward; apex of last dorsal segment cephalad of notch of last ventral by one and one-half times the distance from notch to apex of segment.....**insita** Cress.
Last ventral segment broad, the sides diverging basad, not strongly bent downward.....30

30. Face with many erect brown bristle-like hairs among the appressed light ones; punctures of first abdominal segment laterad less than a puncture-width apart.....**pratti** n. sp.
Face without dark bristle-like hairs; first abdominal segment sparsely punctured laterad.....**octodentata** Say.
31. Last dorsal segment strongly angularly narrowed.....32
Last dorsal segment at most roundly narrowed.....33
32. "Part of last dorsal beyond constriction much larger than wide," **rufitarsis** Smith
"Part of last dorsal beyond constriction almost as wide as long" **comstockii** Cress.
33. "Larger, 13 mm. long".....**lucrosa** Cress.
Smaller, hardly 12 mm. long; abdomen more slender and more closely punctured.....**moesta** Cress.

Cœlioxys obtusiventris new species.

Length about 11 mm. Black, the tegulæ and legs, except coxæ, ferruginous; face coarsely rugoso-punctate, vertex coarsely punctured; the punctures separated by much less than a puncture width; scape and pedicel (rest of antennæ missing) dark, obscurely reddish; face with white hair, dense along inner orbits, interspersed with long bristle-like hairs; mesoscutum and scutellum with punctures as on vertex; scutellum with a tubercle medially on posterior margin; lateral teeth long; mesonotum with pubescence along anterior margin and base of scutellum (badly worn); wings infuscated, apically more deeply so; abdomen sparsely, rather coarsely punctured; segments 1-5 with apical bands of white hair; second, third and fourth segments with transverse furrows, interrupted medially, apicad of these furrows there is an almost impunctate line, the extreme apices of these segments with a few punctures; last segment with a few scattered finer punctures, constricted, the apical portion covered with erect brown hairs, the extreme tip upturned; ventral segments, except apex of last, coarsely, closely punctured, last ventral very broad, not notched, medially produced into a long straight spine, with a very strong fringe of brown hair.

One specimen from the C. F. Baker collection with the record "Florida; Palm."

Type specimen Cat. No. 18217, U. S. N. M.

Although the single specimen is badly rubbed it is described since it is easily separated from the other species having the last dorsal segment turned up at apex and by that segment being almost impunctured. The spine at the apex of the segment is also much longer, in the other species being hardly more than an angulation of the apex.

Cœlioxys alternata Say.

In the table this species occurs twice since the fringe of hairs along the margin of the last ventral segment is not very strong and there might be some difficulty on this account if the species were not listed under both categories

Cœlioxys texana Cresson.

For comparison with *C. hunteri* camera lucida drawings of the last ventral segment and of antennal joints 2-5 of the female are given. (Fig. 1).

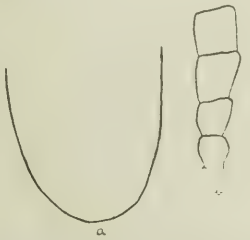

Fig. 1. C. texana Cress. (a) Last ventral segment (b) antennal joints 2-5 of female.

In the antennæ, the third joint is shown to be hardly longer than the second (exclusive of bulbous base) and the fourth is distinctly longer than the third.

Cœlioxys hunteri new species.

Female. Length about 13-15 mm. Black, with red legs; the scape and pedicel, tubercles, carinate lateral edges of pronotum and tegulæ, reddish; lateral margins of basal abdominal segments sometimes obscurely reddish; face rather finely rugoso-punctate with a median impunctate line from in front of anterior ocellus to base of clypeus and indistinctly indicated on clypeus; anterior ocellus enclosed by two cresent-shaped raised impunctate areas which are finely reticulate; upper inner orbits each with a similar sculptured spot; face with rather abundant white hair, thicker along inner orbits and around antennæ;

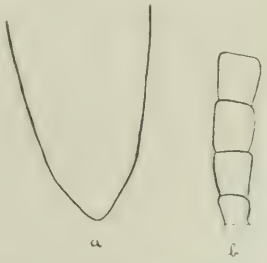

Fig. 2. C. hunteri Cwfd. (a) Last ventral segment (b) antennal joints 2-5 of female.

second joint of antenna (not counting bulbous base) much shorter than third, the third about as long as fourth; (See Fig. 2, b); vertex and mesoscutum with large rather sparse punctures, each with an appressed

white hair: scutellum and its lateral spines shaped about as in **texana**; wings dusky, with the apical margins more deeply infuscated; coxæ black with more or less obscure reddish at apices; tarsi mostly dark; spines on anterior coxæ short; mesonotum at base and along lateral margins with lines of appressed, slightly ochreous hair, at base forming two spots near middle; scutellum at base with two transverse spots of similar pubescence; under side of scutellum at apex and metanotum with dense subappressed white hair; propodeum and pleuræ with long white hair; abdomen shiny, with sparse rather coarse punctures, last segment with a silky lustre the punctures longitudinally elongate, the last dorsal and ventral (Fig. 2, a) segments (Fig. 2, a) shaped about as in **alternata**; basal margin of segment one and apical margins of segments 1-5 with lines of appressed white pubescence; segments 2-4 with diagonal lateral lines of similar pubescence near bases.

Type-locality: Hearne, Texas.

Described from five females collected "at nests in bogs", July 23, 1906, by F. C. Bishopp.

The species is named in honor of Mr. W. D. Hunter in charge of the investigation from which these specimens were obtained.

Type—Specimen: Cat. No. 18218, U. S. N. M.

This species in the structure of the apical plates is near *texana* and *alternata;* the last has dark legs; *texana* has the last ventral segment with almost parallel sides and apically broadly rounded; *altenata* and *hunteri* have this segment narrowed apically and consequently pointed at apex; in *alternata* the last dorsal segment is shiny and with sparse small punctures.

Cœlioxys piercei new species.

Female. Length about 9.5 mm. Black, including the legs, only the apical joints of the tarsi somewhat reddish; face rather finely rugoso-punctate; antennæ black; vertex and mesoscutum closely, coarsely punctured, scutellum slightly coarser rugoso- punctate; face and dorsum of thorax with slightly ochraceous pubescence, more abundant on sides of face and around antennæ and forming lines along anterior and lateral margins of mesoscutum and indistinctly so along base of scutellum; pleuræ with abundant lighter colored hair; lateral teeth of scutellum moderate in length, slightly incurved; tegulæ black; wings slightly dusky with the apical margins broadly deeply infuscated; abdomen closely, rather coarsely punctured, the last segment more closely and finely punctured, segments 2 and 3 with a deep and segments 4 and 5 with a shallow transverse furrow; segments 1-5 with apical bands of appressed white pubescence and segment 1 with the lateral margins with similar hair; base of first segment with an indistinct band of slightly ochraceous hair; last dorsal segment with a median longitudinal carina,

the segment rather suddenly constricted, near apex with a flattened projection on each side of carina (see fig. 3); last ventral segment extending a little beyond last dorsal, seen from below subtriangular in outline, the lateral edges straight, with only weak hair and without a projecting point.

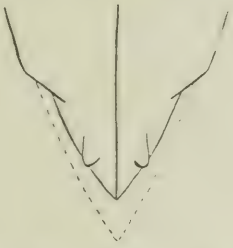

Fig. 3. C. piercei Cwfd. Last dorsal segment of female (last ventral indicated by dotted line).

Described from one female from Cotulla, Texas, April 17, 1906, on *Verbesina encelioides*, F. C. Pratt, collector.

Type—Specimen: Cat. No. 18219, U. S. N. M.

The two curious flattened projections on the last dorsal segment readily distinguish this from any species known to me.

Named in honor of Mr. W. Dwight Pierce who was actively interested in the work which resulted in the accumulation of the splendid collection of Texan Hymenoptera.

Cœlioxys edita Cress.

This species was described from a male. Female from Texas which I have associated with this species are *deplanata* Cress. and I am inclined to think that *edita* should be classed as a synonym of this species, although the association of sexes I have made may be incorrect.

Cœlioxys sculptifrons n. sp.

Female. Length about 11.5 mm. Black, with the tegulæ and the legs, except coxæ, ferruginous; clypeus rugoso-punctate with smaller punctures interspersed, the apical margin with five short teeth; face above insertion of antennæ coarsely, closely punctured, more sparsely so laterad of the ocelli; mesoscutum and scutellum coarsely punctured, the punctures except on disk of scutum crowded; lateral teeth of scutellum short, pointed; sides of face with dense long white subappressed pubescence, pubescence on clypeus finer and not so conspicuous; lateral and posterior margins of mesoscutum with indistinct lines of white appressed pubescence; pleuræ with dense long white hairs; wings dusky, with the apical margin more densely infuscated; apical margins of dorsal

and ventral abdominal segments 1-5 with bands of appressed white pubescence; first abdominal segment rather coarsely and closely punctured: second and third segments with distinct, complete, transverse impressions, the second with rather fine punctures basad of its impression, the punctures about a puncture width apart; apicad of the impression, the punctures sparse averaging two or more times a puncture width apart and finer and sparser toward middle, third segment basad of impression with the punctures somewhat wider apart than on base of second segment; apicad of the impression the punctures about as far apart as on apical part of second segment; fourth and fifth segments apically punctured about as apex of third segment; sixth segment with a distinct median longitudinal carina, basally finely punctured, the punctures slightly more than a puncture width apart; apically the punctures become slightly larger and crowded; near apex on each side of the median carina a depressed area bounded laterally by an elevated margin which is very indistinctly irregularly carinated; ventral segments 1-4 coarsely, closely punctured; fifth coarsely punctured at base, the apical part minutely very closely punctured; last ventral segment with the sides emarginate near apex.

Type-locality: Ithaca, New York.

Described from one specimen with the record, July, 1–7, from the collection of Mr. Nathan Banks.

Type—Specimen: Cat. No. 18220, U. S. N. M.

This species resembles *C. deplanata*, but differs as shown in the table and also by the sparser punctures on the abdominal segments apicad of the transverse impressions on second and third segments and by the sparse punctures on segments 4 and 5. In *deplanata* the punctures on the last segment are coarser at base, the impressions near apex are not so deep nor do they extend so far laterad.

This species differs from *C. immaculata* Ckll. described only in the male sex in the punctation of the second abdominal segment beyond the transverse impression and since the two sexes in this genus agree very closely in such characters, I do not think it possible for this species to be the same as the one described by Prof. Cockerell.

Cœlioxys sayi Robertson.

C. octodentata Cresson (not Say).

The synonomy of Mr. Robertson of this species and of *C. octodentata* Say (*C. altilis* Cress.) is adopted for it is evident that he has correctly interpreted the original description of Say.

Cœlioxys banksi n. sp.

Female. Length about 11 mm. Black, femora black, the rest of the legs ferruginous with the middle of the tibiæ obscured with blackish and the tarsi dark toward apices; face above antennæ very coarsely punctured, the clypeus medially triangularly produced and somewhat reflexed; mesoscutum amd scutellum very coarsely punctured, the punctures well separated on the disk; lateral teeth of scutellum rather short, pointed; scutellum gently rounded posteriorly; middle of face with appressed long white pubescence, clypeus with similar short pubescence; suture between mesoscutum and scutellum with a line of appressed white pubescence, a spot of similar hair at the posterior end of tegulæ; mesopleuræ with the anterior and posterior margins densely clothed with similar pubescence, as is the region immediately in front of and below tegulæ; the punctures of mesoscutum each with a long white delicate hair; tegulæ dark, obscurely reddish on disk and outer margin; wings dusky, with the apical margins more densely infuscated; dorsal and ventral segments 1-5 with apical bands of appressed white pubescence; first abdominal segment rather coarsely and sparsely punctured, the second and third with transverse impressions, basad of them the punctures about a puncture width apart, apicad of them the punctures slightly larger, laterad about as dense as basad of impressions but medially very sparse; fourth dorsal segment punctured about as third, with a transverse impression which is interrupted medially; fifth segment with the punctures finer, basally less than a puncture width apart, apically the punctures more than their own width apart; last dorsal segment with a median carina, the punctures close, the apical production of the last segment almost as long as the basal part of the segment; apex of last dorsal segment basad of notch of last ventral segment by about one and one-half times the length of the distance from notch to apex of segment; ventral segments 1-5 coarsely, closely punctured, punctures on fifth segment decreasing in size apicad; last ventral long, narrow, the apical portion bent downward, the sides near apex with a distinct notch.

Type-locality: Falls Church, Virginia.

One specimen, collected August 20, from the collection of Mr. Nathan Banks, after whom the species is named.

Type—Specimen: Cat. No. 18221, U. S. N. M.

The peculiar form of the clypeus easily distinguishes this species. In this table if this character be omitted the species would run to couplet no. 33, but the two species in that couplet both have the legs entirely black as well as the clypeus differently formed, etc.

Cœlioxys slossoni Viereck.

In the collection of the U. S. Nat. Mus. are two badly rubbed females which agree with Viereck's original description, one with the record "Palm Beach, Fla., 3-'00, collection C. F. Baker", the other without locality from the Ashmead collection. The Palm Beach specimen has the apex of the third segment dusky.

Cœlioxys slossoni arenicola new variety.

Female. Length about 13.5 mm. Differs only in having the abdomen, except basal segment, black (one has segments 2 and 3 in part obscurely reddish) and the wings subhyaline with dusky margins.

Male. Length 10.5 mm. Similar to the female in sculpture and color; the apex of the abdomen with 4 teeth the upper pair blunt somewhat flattened and divergent the lower pair longer pointed subparallel; base of last segment with a tooth on each side; fifth segment not toothed.

Type-locality: Brownsville, Texas, (April 17, 1895, C. H. T. Townsend, collector).

Allotype male from San Diego, Texas.

Other localities: Calhoun, Co., Texas, J. D. Mitchell, collector, one female; Nuecestown, Texas, 4–28–'96, C. L. Marlatt, collector, one male; also two paratype females from Brownsville, Texas, and one male from San Diego, Texas.

Type—Specimen: Cat. No. 18222, U. S. N. M.

It is most probable that the species recorded from Galveston, Texas, by Brues* as *menthae* is this form.

Cœlioxys asteris new species.

Female. Length about 14 mm. (abdomen unduly extended). Black with the tegulæ reddish-testaceous and the legs, except coxæ, ferruginous; face below antennæ finely rugoso-punctate, above antennæ coarsely punctured with an impunctured but lineolate area laterad of each lateral ocellus but none in front of and beside anterior ocellus; third joint of antennæ much shorter than fourth (see fig. 4, b,); reflexed lateral margins of pronotum strongly developed, translucent; mesoscutum with coarse, close punctures; scutellum rugoso-punctate and with a rather indistinct median longitudinal carina; lateral teeth of scutellum rather long, somewhat incurved, thick dorso-ventrad and carinate above along inner edge; wings deeply infuscated, more so along apical margins; abdomen finely, sparsely punctured, segments 2-4 each with a shallow transverse impression broadly interrupted medially; caudad of these furrows the segments almost impunctured; base of last segment more

*Entom. News, XIV, 83, 1903.

finely and closely punctured, the apical constricted portion finely rugoso-punctate; last ventral segment broad, notched near apex (see fig. 4, a,); ventral segments 1-4 rather coarsely punctured, five with similar punctures at base and fine ones at apex.

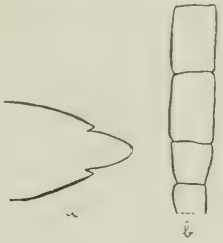

Fig. 4. C. asteris Cwfd. (a) Last ventral segment (b) antennal joints 2-5 of female.

Type-locality: Victoria, Texas.

The type collected Nov. 6, 1904, by Mr. A. J. Leister, "on aster"; a paratopotype with the same date and collector is only about 11 mm. long.

This species resembles *octodentata* which has the third joint of the antennæ almost as long as the fourth.

Type—Specimen: Cat. No. 18223, U. S. N. M.

Cœlioxys coquilletti new species.

Female. Length about 12 mm. Black with ferruginous tegulæ and legs; face below antennæ finely rugose, above, coarsely so without any smooth spots; third joint of antennæ almost as long as fourth; face with abundant pubescence at sides (rest worn ?); mesoscutum coarsely rugose all over; with a short lateral carina on each side near tegulæ; reflexed lateral margins of pronotum strongly elevated, translucent; an interrupted line of appressed white pubescence (worn ?) at base of mesoscutum, a line at base of scutellum and one at lateral margins of mesoscutum;

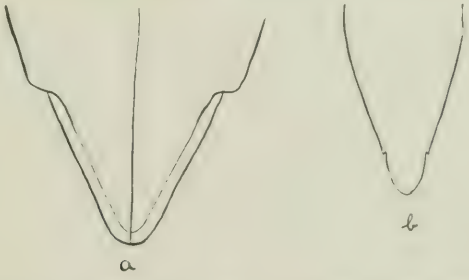

Fig. 5. C. coquilletti Cwfd. (a) Last dorsal segment (b) last ventral segment of female.

scutellum slightly more finely rugose than mesoscutum, the lateral teeth rather long and slightly incurved; propodeum and pleuræ with long white hair; wings slightly dusky with the apical margins somewhat more so; spines on anterior coxæ long; abdomen with the venter largely reddish and the edges of dorsal segments close to venter somewhat reddish (to be seen only from below); first segment of abdomen closely punctured, the punctures laterad separated by less than a puncture width; segment 1 with a basal and segments 1-5 with white apical hair bands; segments 2 and 3 deeply and 4 rather shallowly transversely impressed; the segments basad of the impressions closely punctured, apicad of them very sparsely so; last dorsal segment suddenly angularly constricted, and with a median carina (see fig. 5a); last ventral notched at sides (see fig. 5b); ventral segments 1-5 with apical hair bands and coarsely punctured.

Habitat: Los Angeles, Co. Cal., (D. W. Coquillett, collector).

Type—Specimen: Cat. No. 18224, U. S. N. M.

In general this resembles *octodentata* but differs in the vertex being rugose and without smooth areas, in the rugose mesoscutum (in *octodentata* the punctures on the disk of the mesoscutum are well separated); in the abruptly narrowed last dorsal segment, and in the closely punctured first segment of the abdomen. In this last character it resembles *pratti* but differs in all the other characters quoted above; *pratti* has the mesoscutum more closely punctured than *octodentata* but it is not rugose. In the shape of the last dorsal segment this resembles *rufitarsus* from which it differs in addition to the difference in the color of the legs by the first segment being closely punctured, by having the second and third segments basad of the transverse impressions more closely punctured and by having the fifth ventral, except apex, with coarse punctures, etc.

Cœlioxys insita Cresson.

The apex of the ventral segment as illustrated and marked on the figure is the approximate point to which the last dorsal segment comes (indicated by a U in the sketch). (Fig. 6.)

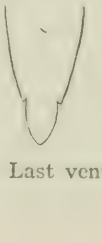

Fig. 6. C. insita Cress. Last ventral segment of female.

Cœlioxys pratti new species.

Female. Length 11.5 mm. Very similar to *C. octodentata* but differs in the clypeus having many erect, brown, bristle-like hairs among the dense white pubescence, the eyes with longer, much denser and distinctly brownish pubescence, the punctures of the mesonotum somewhat finer and denser, the first abdominal segment with close punctures, those laterad separated by much less than a puncture width; fifth ventral abdominal segment with coarse punctures only at base.

One female with the record Kerrville, Texas, April 14, 1907, on *Marrubium vulgare*, H. Durham, collector.

Type—Specimen: Cat. No. 18225, U. S. N. M.

C. octodentata has the punctures of the mesonotum well separated medially, the first segment with the punctures toward sides separated by more than a puncture width and the fifth ventral segment with coarse punctures except on the apex.

This species is named for Mr. F. C. Pratt through whose efforts the large amount of material from the type-locality of this species was secured.

Cœlioxys rufitarsis var. **rhois** Ckll.

This differs from the typical form only in having the tegulæ black and the veins of the wings darker than normal, and would run out in the table where the typical form does.

CONNECTANT FORMS BETWEEN THE MUSCOID AND ANTHOMYIOID FLIES.

By Charles H. T. Townsend,
Director of Entomological Stations, Lima, Peru.

The object of this communication is to point out certain forms which appear to be transitional between the muscoid and anthomyioid types, to call attention to their evident affinities, and to suggest characters which may be used for establishing a boundary line between these two natural groups of flies.

Girschner's system, proposed in 1893, recognizing two groups which he called *Tachiniden* and *Anthomyiden*, contains many elements of truth. It has resulted in demonstrating muscoid affinities in certain forms hitherto accepted without question as anthomyioid. Bezzi and Stein have followed this system in their catalogue, and Schnabel and Dziedzicki have recently attempted to reinforce it in their treatment of the anthomyioid flies. What concerns us chiefly in the present consideration is the fact that *Musca* and its immediate allies fall in the *Anthomyiden* according to this system. The concept is fundamentally wrong nomenclatorially, however it may be justified otherwise. Whatever group *Musca* is found to fall in must take its name from that genus. If Girschner's group *Anthomyiden* be adhered to as it stands, its name must be *Musciden* according to all accepted rules of nomenclature. But it is certain that many characters remain to be investigated before this grouping can safely be pronounced a natural one, for the main separation is founded practically on a single character—the presence or absence of hypopleural bristles.

The solution of the question practically hinges on whether *Musca* is, or is not, more closely allied to *Anthomyia* than it is to *Calliphora*. Wherever *Musca* goes, it will carry with it a considerable contingent—*Stomoxys*, *Muscina*, *Mesembrina*,

Glossina, all their immediate allies, and quite probably a block of forms hitherto classed as Anthomyiidæ. The position of *Calliphora* has never been questioned, but the other forms are more or less connectant between *Calliphora* and *Anthomyia*, and the affinities of *Musca* have long been confused with those of the truly connectant forms. We are thus practically in the rather paradoxical position of being unable to place taxonomically the type of the superfamily Muscoidea, which seems inclined to fall in the Anthomyioidea.

If *Musca* prove to be more nearly related to *Anthomyia* than to *Calliphora*, then one of two things must result. Either the Muscoidea in the writer's sense must extend itself to include all the anthomyioid flies; or the latter must be grouped with *Musca* and the connectant forms into a totally different superfamily to be known as the Muscoidea, thus completely changing the sense of the name and leaving the Calliphorinæ and higher groups to form a superfamily by themselves. It is therefore evident that a pressing necessity exists for fixing definitely the status of *Musca* with relation to the connectant forms that intervene between *Anthomyia* and *Calliphora*.

Certain students, not caring to proceed farther, will adopt the former solution of the difficulty and thus dismiss the whole subject. But this is not the correct solution, for it obscures the real affinities of the two groups. The anthomyioid flies, as a whole, present a far greater contrast with the rest of the Schizometopa, which is to say Muscoidea, than do the various groups of the latter with each other. Moreover, there are at least two family types— *Coenosia* and *Anthomyia*—represented in the Anthomyioidea, and it is a question whether *Drymeia* does not constitute a third and *Fannia* a fourth. Nor can we reduce the value of the taxonomic groups one notch, thereby considering the whole Schizometopa as one superfamily, for such action would only compel the inauguration of a new category farther down the line in order to preserve a proper conception of relationships. The anthomyioid flies constitute a superfamily of the atypic class, which is to say that they occupy a position entirely outside the proper limits of the superfamilies Muscoidea and Borboroidea (Holometopa excl. Conopidæ), but intermediate between the two. As such they claim separate recognition.

In order to fix permanently the taxonomic status of *Musca*, a comparative study must be made of *Anthomyia pluvialis* L., *Calliphora erythrocephala* Mg., *Musca domestica* L., the connectant forms and the main anthomyioid types, along the following lines:

(1) Chaetotaxy.

(2) Pilotaxy—This term is coined to designate the disposition of hairs and pile in the Diptera in general and the Muscoidea in particular.

(3) Pleural and other external thoracic anatomic characters.

(4) Venation.

(5) Male reproductive system.

(6) Female reproductive system.

(7) Hypopygium.

(8) Egg.

(9) First-stage maggot.

Lowne has worked out *Calliphora erythrocephala* quite extensively, and Hewitt has done the same for *Musca domestica*. *Anthomyia pluvialis* needs similar attention before exact comparisons can be instituted. As to male reproductive-system characters in the connectant and anthomyioid forms, *Stomoxys* has been worked out by Roubaud, and verified by others including the writer. *Othellia*, *Haematobia*, *Hypodermodes* and *Morellia* have been worked out by Thompson, the last two not yet published; *Muscina*, *Synthesiomyia*, *Morellia*, *Limnophora*, *Leucomelina*, *Fannia* and Gen. Indet. have been worked out by the writer. In addition to these many nonconnectant muscoid forms have been investigated as to the male reproductive system by both Thompson and the writer, and *Auchmeromyia* and *Choeromyia* have been similarly worked out by Roubaud. All of the above named connectant and anthomyioid genera except *Fannia* agree with *Musca* in lacking the male accessory glands. *Fannia* and all the nonconnectant muscoid forms possess such glands, though they may be rudimentary in the higher forms.

The writer has worked out the female reproductive system and egg in *Stomoxys*, *Muscina*, *Synthesiomyia*, *Leucomelina*, *Limnophora* and *Spilogaster*, besides many nonconnectant muscoid genera. The first three agree with *Musca* and the Calliphorinae in egg characters, but the last three differ considerably from them in these characters. Available data on the lines above specified are presented below.

CHAETOTAXY AND PILOTAXY.

Higher Muscoidea	Hypopleural bristles present in a more or less vertical row, pteropleural bristles present; when 3 sternopleural bristles present, their formula is either 2.0.1 or 1. 1. 1—All muscoid families except Muscidæ, Oestridæ, Cuterebridæ.
	True hypopleural bristles present, pteropleural bristles absent but in their place hairs or pile; sternopleural bristles 2. 0. 1 or 1.0.1—Bengaliinæ (Calliphorinæ).
	Macrochaetæ entirely absent; row of hypopleural hairs present homologous with true hypopleural bristles—Gastrophilus and Cobboldia.
Typical Muscoidea.	True hypopleural bristles absent, hypopleural hairs and pile absent; pteropleural bristles present, also often pteropleural hairs or pile; sternopleural bristles 1. 0. 2—Musca, Morellia and Glossina.
Connectant Muscoidea	Hypopleural hairs present, pteropleural hairs absent; sternopleurals 1. 0. 2 or 0.0.2—Synthesiomyia and Graphoymia.
	Hypopleural hairs and bristles both absent; pteropleural hairs, sometimes of a bristly nature, present; sternopleurals none, 0.0.1, 1.0.1, or 1.0.2-1—Haematobia, Hypodermodes, Mesembrina, Eumesembrina, Pyrellia, Orthellia.
	Hypopleural and pteropleural hairs present; sternopleurals 0.0.1—Stomoxys.
	Neither hypopleural nor pteropleural hairs, pile or bristles present; sternopleurals normally only 3 and formula 1.0.2 (abnormally 2.0.2)—Muscina, Myospila, Clinopera, Leucomelina, Gen. Indet., Limnophora, Aricia, Spilegaster.
Anthomyioidea	Neither hypopleural nor pteropleural hairs; sternopleurals 3 or more and rarely 1.0.2—Anthomyia, Fannia, Coenosia.

PLEURAL ANATOMY

The name *squamopleura* is hereby proposed for the inferior swollen lobe of the metapleura of authors, being the lower lobe of the lateral plate of postscutellum (Hewitt). The sclerite in question is a part of the mesothorax. The term metapleura is thus misapplied here, since metapleura can have no place in mesothoracic terminology. The metathorax is represented in the Muscoidea by the metasternum, whose lateral wings are termed the hypopleuræ; and by the true metapleura which is situated behind the hypopleura, the metanotum being practically evanescent.

The squamopleura exhibits characters in connection with the hypopleura and the posterior thoracic spiracle which are at times of importance. It therefore requires a special designation though it is not apparently a separate sclerite. It is sometimes bare, often pilose or hairy, sometimes bristly, while the position of the spiracle with reference to it and the hypopleura may be used in the separation of groups among the connectant forms.

Higher and Typical Muscoidea	Posterior thoracic spiracle behind vertical axis of squamopleura and hypopleura—Musca, bulk of Muscoidea, Leucomelina, Limnophora, Spilogaster, Gen. Indet., Fannia.
Anthomyioidea Connectant Muscoidea	Posterior thoracic spiracle squarely interposed between the squamopleura and hypopleura—Muscina, Synthesiomyia, Morellia, Aricia (last judged from figures).

VENATION

Higher and Typical Muscoidea	Fourth vein when complete or apical crossvein when present reaching margin at or before extreme wingtip, the hind crossvein always joining fourth vein well before bend of latter or origin of apical crossvein—Musca, bulk of Muscoidea, but including only Cobboldia among the Oestridæ and allies.
	Fourth vein always complete and reaching margin before wingtip, the apical cross-vein not present, the hind cross-vein practically in line with the last section of the fourth vein—Glossina, Cuterebridæ, Hypoderminæ, Oestrinæ.
	Fourth vein incomplete, not reaching wing margin; apical and hind cross-veins obsolete—Gastrophilus.
Connectant Muscoidea	Fourth vein always complete, reaching margin behind extreme wingtip, always bowed forward apically; no apical crossvein—Stomoxys, Haematobia, Lyperosis, Hypodermodes, Eumesembrina, Muscina, Myospila, Clinopera, Pararicia, Leucomelina; the last three with least forward bow to fourth vein and thus most approaching the anthomyioid type.
Anthomyioidea	Fourth vein not bowed forward in any part of its extent, but often bowed backward apically—Limnophora, Spilogaster, Fannia and other Anthomyioidea.

Of the above Haematobia furnishes an aberrant form of the *Stomoxys* type, and *Glossina* an aberrant form of the *Musca* type. Only *Clinopera*, *Pararicia* and *Leucomelina* are intermediate between the *Stomoxys* and *Anthomyia* types. A number of forms are intermediate between the *Stomoxys* and *Musca* types.

	Reproductive System.
Higher Muscoidea	Male with accessory glands always more or less developed, at least their rudiments visible; female usually with a large number of ovarioles—All Muscoidea down to and including the Calliphorinæ.
Typical Muscoidea	Male without accessory glands, with very long and curled ejaculatory duct whose head is developed into a very elongate vesicula seminalis; female without uterus, with many functioning ovarioles—Musca, Muscina, Synthesiomyia.
Connectant Muscoidea	Same as preceding, but ejaculatory duct of male much shortened, not over 3 to 5 times as long as the vas deferens, with more than half of it functioning as vesicula seminalis—Morellia, Stomoxys, Haematobia*.
	Male without accessory glands; female with only one or two functioning ovarioles, one or two maggots or eggs developing at a time in the uterus—Glossina,* Dasyphora,* Mesembrina, Hylemyia.*
	Male without accessory glands; female with few ovarioles, depositing large eggs which hatch shortly into maggots omitting the second stage and developing rapidly—Hypodermodes, Eumusca,* Myospila.*
	Male without accessory glands; female with few ovarioles, depositing a small number of large eggs—Orthellia, Graphomyia,* Pyrellia.*
	Male without accessory glands, with very long vas deferens communis present and long vesicula seminalis; female with few ovarioles, depositing a small number of large eggs—Leucomelina, Limnophora, Spilogaster*.
	Male without vas deferens communis or accessory glands, with very short ejaculatory duct—Gen. Indet.
Anthomyioidea	Male without vas deferens communis, with accessory glands, with bulbous vesicula seminalis at head of the very short ejaculatory duct—Fannia.

The term *vas deferens communis* is here proposed for the slender tube present in some forms extending from the union of the two vasa deferentia to the beginning of the swollen and more or less elongate vesicula seminalis, and apparantly not to be interpreted as a part of the ejaculatory duct. It is short in certain Borboroidea (*Paralimna* sp. for example) and Syrphoidea (*Volucella* sp.), but very long in *Leucomelina* and *Limnophora*. It seems to be the homologue of the common oviduct of the female, notwithstanding Berlese's homologies in his Gli Insetti (p. 841).

*Some doubt exists as to whether the 9 starred genera agree with the male characters given.

HYPOPYGIUM

Worked out by Schnabl and Dziedzicki for a large number of connectant as well as true anthomyioid forms. The characters agree in a general way throughout the connectant forms much as do those of the female reproductive system, not appearing to furnish variations of sufficient scope for definite separation into two main groups, except to mark off the Coenosiidæ from the other forms. But they will doubtless be of much use in the separation of small groups. The Calliphorine and higher muscoid groups need the same careful study for comparison with the excellent results of these authors on the forms which they have investigated.

EGG

Leucomelina, *Limnophora* and *Spilogaster* differ considerably in egg structure from *Musca*, *Muscina*, *Synthesiomyia*, *Stomoxys*, the *Calliphorinæ* and higher groups. They deposit a small number of very large elongate eggs, either heavily striate longitudinally or ribbed, or very minutely scaled-reticulate, very slightly curved, yellowish-whitish in color, with thick chorion, translucent-enameled in appearance.

It is probable that these approximate the characters of the eggs of *Orthellia*, *Graphomyia*, *Pyrellia*, *Myospila*, *Eumusca* and *Hypodermodes*, all of which deposit only a small number of very large eggs.

The egg may be expected to furnish important characters for the separation of the connectant forms.

MAGGOT

The position of the anterior spiracle in the third-stage maggot of *Fannia* is quite in contrast to its position in *Musca*, being situated well forward on the third segment. Whether this holds good for *Anthomyia* and *Coenosia* is doubtful. The first-stage maggot characters, especially the cephalopharyngeal skeleton and anal stigmata, should differentiate the connectant forms from the true anthomyioids.

It appears from the foregoing that the most serviceable characters for defining the natural boundary between *Musca* and *Anthomyia* will be found in the egg, first-stage maggot, male reproductive system, chaetotaxy and pilotaxy; while the venation, thoracic sclerites, female reproductive system and hypopygium will furnish supplementary characters of value.

The indications from the very incomplete data which it has been possible to present are that *Musca* is much more nearly related to *Calliphora* than to *Anthomyia*, but final judgment must be reserved until all the main types concerned can be investigated and the results compared and correlated. The present meager notes will form a starting point for an extended study of the subject.

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